REPORT ON FUTURE DETECTOR REQUIREMENTS AT ESRF

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LIST OF CONTRIBUTORS

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EXECUTIVE SUMMARY

Purpose of the study
The ESRF is the European centre for synchrotron radiation based X-ray research (one of three high energy synchrotron sources operational worldwide). In 2009, a ten-year Upgrade Programme was initiated in order to maintain the success of the facility and to offer new scientific and technical opportunities to the users. In the frame of this programme, a large effort is planned to make improvements to the X-ray detection systems.

The purpose of this study is to compile information on the present situation and the expected needs in terms of X-ray detection for all the ESRF beamlines in the next 10 years. The aim is not to evaluate the various potential technologies but to describe the beamline needs with references, when appropriate, to existing technologies or foreseen technical developments.

This report mainly constitutes a working tool which aims at helping future decisions by summarising all the cases in a single document with a level of information as homogeneous as possible.

Limitations of the study
This document tries to be as complete as possible but is obviously non-exhaustive. It is a picture of the future detection needs of beamlines as they can be imagined at the moment the report is written. The information is expected to change as the beamline instrumentation and scientific applications evolve.

Only photon detectors are concerned by this study and therefore electron or spin detection have not been considered. Incident beam intensity and position monitors are not taken into account either.

Finally, other limitations have to be underlined. This document results from the interaction between the beamlines and the detector group and presents the view of the detectors by combining both points of view; it also tries to provide a level of detail that is as homogeneous as possible for all the applications. In practice, it turned out to be impossible to gather complete information for all the cases due a series of circumstances such as the variable level of maturity of the foreseen techniques or uncertainties in the way some experiments will be implemented, for instance. Consequently, some parts of the report are much more detailed and quantitative than others, which merely provide a qualitative description of certain detector characteristics.

First observations
Collected needs have been grouped in sections called “detector cases”, as it is explained in the next section, “Applied methodology”.
32 detector cases have been identified and described: 5 point detector cases, 25 position sensitive detector cases and 2 energy dispersive detector cases. These descriptions are expected to evolve with the technical possibilities and the scientific needs. Nevertheless, several directions can be outlined.
✓ **Point detectors** remain necessary for some applications (absorption spectroscopies, polarization measurements) but it is expected that in many cases their replacement by position sensitive detector will increase the overall efficiency of the experiment, by avoiding having to scan the detector and thus being able to perform time-resolved experiments, or enhancing the energy resolution in wavelength dispersive set-up.

✓ **Position sensitive detectors** constitute the majority of described requirements.

- **Linear detectors** appear necessary for few beamlines and might be replaced in some cases by **area detectors**. Nevertheless, this may be detrimental to readout speed, and thus not always advisable.

- **Area detectors** may concern 27 beamlines (several beamlines needing more than one). Thus specifications are spread over a very broad range (e.g. pixel size going from less than 1 µm to 1 mm) and several technologies will be necessary to address all the needs: indirect detection with optical coupling or fibre-optic taper between scintillator and sensor, pixel detectors, APD arrays.
  - The **number of pixels** is expected to increase in many cases.
  - **Speed** is not presented as the main priority provided that the readout time is reasonable compared to the few milliseconds of exposure time. High speed concerns only a few beamlines.
  - **Energy resolution** is presented as useful or even necessary in many cases, going from scattering and diffraction to inelastic spectroscopies. If resolutions around a few percent appear interesting for all these experiments (elimination of fluorescence background, cosmic rays, harmonics), a resolution of a few tens of eV would be necessary to suppress Compton background from diffraction and scattering patterns.

✓ **Energy dispersive detectors** are the main detectors for only 4 beamlines but they are required by more than 12 projects as auxiliary detectors or needed for occasional experiments. Existing technology appears quite satisfactory, except for high energies. For energies below 15-20 keV, the main expected improvement concerns engineering aspects (such as solid angle coverage, mechanics, electronics and software) in order to increase the global efficiency of the experiments. EDX arrays could speed up some experiments such as confocal microscopy and improve the resolution of energy dispersive diffraction set-ups.
In order to acquire a first global vision of the requirements, a detailed questionnaire was sent to the beamlines in January 2007 before the start of the ESRFUP project. The answers to that questionnaire were taken as a starting point for this study.

**Step 1:** The answers to the questionnaire were gathered and classified as a function of their similarities in terms of both technological issues and analysis techniques. All this information was compared and completed with the descriptions of beamline projects presented in the ESRF 2008-2017 Science and Technology Programme (*Purple Book*).

**Step 2:** Series of meetings with beamlines staff were organised and during these meetings, spokespersons for each beamline were also identified. Each meeting focused on one application (e.g. imaging, high energy diffraction, scattering…), generally grouping together several beamlines, or only one, if no *a priori* similarities with other beamlines could be identified. A general description of the needs was defined, confirming or not, the possibility of considering several beamlines together for each given application.

**Step 3:** Spokespersons were met individually in order to describe as precisely as possible the type of detectors they need, the required specifications and the expected improvements with respect to the current situation.

**Step 4:** Individual “detector cases” were defined, corresponding to a particular set of specifications and operating conditions addressing the needs of one or more experimental stations for a particular type of application. For each detector case, a description was written and sent to the concerned spokespersons. All these descriptions constitute Part A of the report.

**Step 5:** Several iterations of discussions with detector group and beamline staff made it possible to clarify and complete as fully as possible the expressed needs.

**Step 6:** The main detector requirements were summarised and compiled in a small number of tables dedicated respectively to point detectors, linear detectors, area detectors and energy dispersive detectors in order to give a simplified global view of the collected requirements. These tables form Part B of the report.
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* Updated following the Floor Plan of 23/04/2009.
PART A:
DETAILED DESCRIPTIONS OF DETECTION NEEDS
This part describes the specifications and needs expressed by the beamlines. Each description corresponds to a rather well-identified detector case, as defined in the “applied methodology” section. The various detector cases follow a similar layout:

- A table indicates which beamlines are interested by the described detector case and for which application.
- **Aim of the detection system**: a brief description of the experiment, with a simplified scheme, gives an overview of the detector configuration and purpose.
- **Operating conditions and specifications**: details, as quantitative as possible, of the main characteristics of the experimental set-up and the target detector specifications: energy range, integration time, energy resolution, spatial resolution, efficiency, dynamic range, linearity, flux on detector, particular experimental conditions, and if necessary other comments.
- **Required detector(s)**: a summary of the main characteristics briefly defines the needed detector.
- **Existing detector(s)**: when it is pertinent, the detectors used today for the same type of application.
- **Short term possibilities**: options considered by the beamlines to fulfil, at least partially in the short term, the needs that are described in each specific case.
- **Main required improvements**: summarises the main improvements to current systems, or most challenging goals, as well as the priorities.
- **Other types of detectors**: gives cross references to the other detectors that are required by the same beamlines.

The different detector cases are grouped into 3 chapters: chapter 1 is dedicated to point detectors, chapter 2 is dedicated to position-sensitive detectors and chapter 3 is dedicated to energy dispersive detectors.
## Chapter 1: Point Detectors

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**Aim of the detection system**

The aim of the detection system is to count photons and to determine their polarization in order to record magnetic diffraction spectra. The same system can also be used by the UPBL07 beamline.

![Diagram of magnetic scattering setup]

**Operating conditions and specifications**

*Energy range:*
The energy ranges mostly from **4 to 10 keV**, and is occasionally extended to 20 keV.

*Integration time:*
The number of scattered photons being very small, the integration times range from **0.5 s to 30 s**.

*Energy resolution:*
Energy resolution is required to suppress fluorescence background and cosmic rays.

*Spatial resolution:*
The main detector will probably remain a **point detector** with an area of about **5 x 5 mm²**. It will be used combined with crystal analysers in order to determine the polarization with a reliability better than 95% (if a beam is 100% horizontally polarized, the polarization should be detected as horizontal at more than 95%). For this application, an area detector could be used only if it is able to reach this precision and, at the same time, to discriminate the high fluorescence background.

**1D** spatial resolution could be used to find more rapidly the scattered peak in the exit cone defined by the magnetic coil aperture (7-degree high). An array of diodes or APD (1 x 1 mm²) covering a height of 50 mm could be scanned horizontally along the aperture. It would be used as a preliminary measurement and should not be a sophisticated system.

**2D** spatial resolution could be used for powder magnetic scattering experiments or coherent diffraction (see PMF project page 50). It could also be useful for screening the homogeneity of the sample and choosing the ideal probing point. For powder diffraction, 1kx1k with 200 to
500 µm pixel size would be used in indirect detection. For coherent diffraction, direct detection is necessary. 1kx1k with 10 µm pixel size would be required.

**Efficiency:**
Since the flux on detector is low, the efficiency of the overall detection system has to be maximised.

**Dynamic range:**
A large dynamic range (16 bits) is necessary because very weak (few counts per second) and very strong peaks (Bragg peaks, up to $10^{12}$ photons/s) have to be measured on the same sample, without having the possibility of varying a lot the incident flux. Indeed, varying the flux generates changes of the thermal load on the sample and can modify the observed properties. Both high and low intensities have to be measured accurately because the intensity of the Bragg peaks is used to compare the magnetic peaks between one another.

**Linearity:**
For the same reason as above and also for correct normalisation of $I$ by $I_0$, a good linearity on the whole dynamic range is required. This is the *sine qua non* condition for the use of the beam in any machine mode. To obtain the same linear behaviour on $I$ and $I_0$, and thus improve the normalisation, the same system should be used for both $I$ and $I_0$ measurements.

**Flux on detector:**
The expected flux on detector can vary from a few counts per second to $10^{12}$ photons/s, in which case the beam has to be attenuated (but as little as possible).

**Particular operating conditions:**
The detector is operated in a high magnetic field. Thus, both the head and the electronics (if placed near the head) should be insensitive to magnetic field. It is mounted on a diffractometre arm and thus should not exceed about 5 kg.

**Required detector**
The needed detector has to be single photon counting detector, ideally with determination of the photon polarization. If this detector has to be used by the UPBL07 beamline, it will have to be UHV compatible.

**Existing detectors**
Currently, avalanche photodiodes are used. The reduction of efficiency above 8 keV is the main drawback today. Nevertheless, it has the direct advantage of eliminating the cosmic rays. The photon polarization is determined by means of crystal analysers. If well chosen, these crystals can also eliminate the fluorescence background. Obviously, these crystals absorb part of the small number of photons scattered by the sample.

Vortex® SDD detectors have been tested. Efficiency in the highest energy range is better than in APD. The energy resolution, even if much better than in APD, is not sufficient to discriminate the interesting elastic signal from the $K_β$ fluorescence line.

**Short term possibilities**
In order to improve the efficiency, the effective thickness of the APD could be increased (by using thicker chips and/or by tilting them). The windows have to be optimised (e.g. using Be windows instead of Kapton).
Main required improvements
The main expected improvements concern the detection efficiency and the determination of the polarization by the detector itself.
Aim of the detection system
The aim of the detection system is to count with very high time resolution the photons produced by the decay of nuclear excited states (delay) after the exciting pulse (prompt) in order to measure several nuclear scattering processes (nuclear forward scattering, nuclear small angle scattering, nuclear Bragg diffraction).

Operating conditions and specifications
Energy range:
The energy ranges from 6 to 100 keV, with a particular emphasis at 14 keV (iron resonance).

Time scale considerations:
The studied phenomena happen in a time scale of a few hundred nanoseconds, thus the detector must provide a time resolution better than the ns. For some isotopes, the lifetime of the nuclear excited state is even shorter and a 100 ps time resolution can be necessary. Even more crucial than the time resolution is the ability of the detector to be ready to count few photons from the “delayed counts” immediately after the exposition of the sample to the high photon flux of the “prompt pulse” (typically after less than 10 ns).

Energy resolution:
Energy resolution is not needed.
Spatial resolution:
Point detectors will continue to be used but 2D detectors can be useful for small angle scattering and for the study of dynamic structures (q dependence of the diffraction pattern). In most cases, a spatial resolution of 100 µm would be convenient.

Efficiency:
To reach the desired time resolution, APDs are used. In order to improve the detection efficiency at high energies, the APD can be chosen thicker and/or tilted to increase the effective thickness seen by the photons. Nevertheless, this has two drawbacks. First, if the detector chip collects more photons, it can saturate the electronics. Second, in thick diodes, the time of propagation of the electrons is not negligible compared to the studied time structures. Thus, one loses time resolution, which is even worse at high energies than at lower ones because the lifetime is shorter.
In order to avoid those drawbacks, the efficiency is increased by stacking several diodes one behind the other and by synchronizing the corresponding electronics.

Dynamic range and linearity:
The detector must be able to count single photons as well as support the high intensity of the prompt pulse ($10^{10}$ to $10^{11}$ photons/s). It can be noticed that measuring the intensity of the prompt pulse is not needed and that the signal can be gated so that it does not reach the counter.

Flux on detector:
The expected flux on the detector can reach $10^{11}$ photons/s in the prompt pulse (that is 70 000 photons in the pulse) and ranges from 0.01 photon/s to $10^5$ photons/s in the delayed signal.

Particular operating conditions:
The detector is operating near magnetic fields. Intents have been made to put it inside the cryostat in order to increase the detection solid angle. Even if up to now the low temperatures have disturbed the avalanche process in the diodes, the eventuality can be kept in mind. The detector is mounted on a diffractometre arm.

Required detector
The required detector must be fast, with high count rate, good time resolution and be capable of making a very fast recovery after high flux exposure.

Existing detectors
The current detectors are APDs connected to fast electronics: (amplifier, constant fraction discriminator, time to amplitude convertor and then ADC and MCA to record the signal). For the highest energies, up to 24 APDs are staked in order to improve the efficiency.

Short term possibilities
The chosen technology is likely to remain APD, with improved electronics. Projects for developing 1D and 2D APD arrays are starting (XNAP project).

Main required improvements
The main expected improvement concerns first the ability of the electronics to resolve high count rates very rapidly. Then, the aim is to have 2D detectors using the same technology.
Absorption spectroscopy in transmission mode

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**Aim of the detection system**
The aim of the detection system is to measure the photon beam intensity before and after the sample in order to record X-ray absorption spectra.

**Operating conditions and specifications**

*Energy range:* The energy ranges from 4 to 30-40 keV.

*Integration time:* PMF needs acquisition times around 1 ms. TEXAS/EXAFS will use acquisition times between 1 ms and 1 s.

*Dynamic range:* PMF requires an acquisition system working with 16 bits.

*Linearity:* For TEXAS/EXAFS measurements, linearity is the critical point, both for I and I$_0$.

*Flux on detector:* On TEXAS/EXAFS beamline, the flux on the detector is expected to be similar to that on BM29, that is $10^8$ to $10^9$ photons/s. On PMF, $10^{12}$ photons/s are expected.

*Particular operating conditions:* At PMF, the detector will be operated near high magnetic fields (30 T) that may generate stray fields up to 0.1 T.

**Existing detectors**
BM29 is currently using ionization chambers for both I and I$_0$, set-up well adapted for the low fluxes available on a bending magnet beamline, and occasionally integrating diodes to perform EXAFS in reflection geometry.

ID06 is currently using ionization chambers for absorption and dichroism experiments.
Other types of detectors

*PMF* requires also 2D detectors (see pages 44, 50 and 59) and energy dispersive detector (see page 94).

*TEXAS/EXAFS* requires also energy dispersive detector (see page 94) and a 2D detector for diffraction experiments (see page 48).
**Differential spectroscopy in total fluorescence yield mode**

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### Aim of the detection system

The aim of the detection system is to collect fluorescence photons in order to record absorption spectra and to obtain from them dichroic signals.

![Diagram of detection system](image)

### Operating conditions and specifications

**Energy range:**

The energy ranges from **1.5 to 20 keV**.

**Integration time:**

The integration time ranges from **hundreds of seconds to milliseconds** and will be shortened to a few nanoseconds for particular experiments.

**Energy resolution:**

Energy resolution is necessary only for some experiments, in order to suppress background coming from an element with absorption edge near the studied edge. This case is mentioned on page 94.

**Spatial resolution:**

Spatial resolution is not required.

**Efficiency:**

In order to avoid over-illumination of the sample (and of all beamline optical elements, that could compromise the stability of the measurement), the efficiency of the detector has to be maximised.

**Dynamic range:**

Since the purpose of the beamline is to detect differential signals smaller than $10^{-6}$ with respect to the absorption edge jump, the dynamic range has to be maximised by carefully reducing the noise of the detector.
Linearity:
For the same reason, linearity on an extended range of intensities has to be reached on both main detector and incident flux detector.

Flux on detector:
In order to optimise the use of the detector characteristics (linearity and signal to noise ratio), the flux is adjusted so that the measured currents range from 0.1 pA and 1 µA. To give an equivalent in terms of photons on a Si diode, 0.1 pA corresponds to 3000 photons of 1 keV.

Particular operating conditions:
The detectors will be operated in ultra-high vacuum, near high magnetic fields up to 6 T.

Existing detectors
ID12 is using Si pnn+ photodiodes operated in the photovoltaic mode and optimised for the beamline by Eurisys-Mesures [Goulon et al., 2005]. The dark current on both I and I₀ is measured alternatively with the fluorescence signal using a chopper at a typical frequency of 67 Hz.

Short term possibilities
A patent (FR08/55566, Goulon et al.) has been registered concerning a detector for the measurement of ferromagnetic resonances at GHz frequencies.

Main required improvements
The main expected improvement concerns the detection of signals of very low intensity at high frequencies.

Other types of detectors
Circular Polarization Beamline also uses an energy dispersive detector (see page 94).
Soft X-ray absorption spectroscopy in total yield mode

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**Aim of the detection system**

The aim of the detection system is to collect fluorescence photons (total fluorescence yield: FY) or electrical current from sample to ground (total electron yield: TEY) in order to record X-ray absorption spectra and to extract from them dichroic signals. In the TEY case, detection consists on electrically insulating the sample and connecting it to an electrometer. It is the main technique used on the beamline. FY is only used in very dilute systems or particular cases as a complement to TEY detection.

**Operating conditions and specifications**

*Energy range:*
The incident energy ranges from 0.4 to 2 keV.

*Integration time:*
Spectra are mostly acquired in continuous mode (energy is scanned continuously and not step by step). Typical integration times are less than 1 second per point. Currently, the lower limit of the integration time for TEY is given by the time constant of the electronics, specially at high gains, around 100 ms. For FY, it is mostly given by the photon flux.

*Dynamic range:*
The measured intensity (current coming from the sample in TEY or current coming from the diode in FY) ranges from $10^{12}$ to $10^{7}$ A. It is mostly composed of the intrinsic background (various emissions of the whole sample and substrate): the absorption edge is expected to be few percent of the background level and the interesting features can be as small as $10^{6}$ of the background level. The currently used voltage-to-frequency converter has a dynamic range of $10^{7}$ over 1 s, which appears as a minimum.

*Linearity:*
Linearity on the whole dynamic range is of particular importance for XAS and XMCD spectroscopies.
**Flux on detector:**
For fluorescence yield, the flux on the diode (with active size around 500 mm\(^2\) at 25 mm from the sample) is around $10^7$ photons/s. In both electron and fluorescence yields, the collected intensity ranges from $10^{-12}$ to $10^{-7}$ A (with typical gains of $10^{11}$ to $10^7$), fluorescence yield being in the lower part of the range.

**Particular experimental conditions:**
The fluorescence detector is operated in ultra-high vacuum and thus should be bakeable, should not pollute the vacuum and should be windowless, but protected by ultra-thin windows (0.1 µm thick) to prevent electrons, ions, luminescence coming from the sample to reach the diode. It will be operated near high magnetic fields.

**Required detectors**
The beamline will continue operating with Si photodiodes totally compatible with magnetic fields and ultra-high vacuum. The main need concerns the electrometers that have to be the fastest and with the lowest possible noise, in order to gain in speed for TEY measurements.

**Existing detectors**
In both total electron yield and total fluorescence yield measurements, the current is detected by high quality electrometers mainly from Novelec and also from Keithley. For fluorescence measurements, large Si photodiodes are used, either from Canberra-Eurisys or from IRD. The diodes from IRD are large (500 mm\(^2\)), very thin (10 to 55 µm effective thickness – thus only convenient for this low energy beamline) and bakeable.

**Main required improvements**
The main required improvement concerns the speed and quality of the electrometers.

**Other types of detectors**

*UPBL07* requires also 2D detectors (see page 52 and 54) and energy dispersive detector (see page 94). The needs for electron / spin detectors are not detailed in this report.
### Chapter 2: Position Sensitive Detectors

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Absorption spectroscopy in energy dispersive mode

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**Aim of the detection system**

The aim of the detection system is to collect photons with 1D spatial resolution in order to record a whole EXAFS spectra in one single exposure.

![Diagram of beam coming from polychromator, sample, and detector]

**Operating conditions and specifications**

*Energy range:*

The energy ranges from 5 to 30 keV.

*Integration time:*

Current integration time is around 1 ms and must be shortened down to
- 1 µs in the continuous mode.
- less than 0.7 µs in the pump-and-probe mode in order to benefit from the temporal structure of the beam: in the 4-bunch mode, the photon bunches are 100 ps long and separated by ~0.7 µs. With 0.5 µs integration time and synchronization with the electron beam, one can probe one 100 ps-bunch. The readout time should not be much longer than the integration time.
- less than 100 ps in a more ambitious scenario consisting in exploring phenomena inside the duration of a bunch in continuous mode.

*Energy and position resolution:*

In the energy dispersive EXAFS strategy, the energy resolution is given by the spatial resolution of the detector, coupled with beamline characteristics (Darwin width of the crystals, beam divergence…). A resolution of 50 µm on a 2048-channel detector placed at 4 m from the polychromator gives a sufficient energy resolution for EXAFS spectroscopy, that is around 0.5 eV on a spectrum of 1 keV-wide. Energy resolution is not required for the detector itself.

*Efficiency:*

Efficiency is not the most critical point, since many photons are presently lost, due to saturation of the detector. Good signal to noise ratio can already be obtained at short exposure times (accumulating several spectra). Nevertheless, better efficiency would be useful in the higher energy range and for very fast acquisitions.
Dynamic range:
It is necessary to record the signal both before and after the absorption edge with a signal to noise ratio better than $10^3$, in order to detect correctly both pre-edge features and EXAFS oscillations (with an amplitude down to 1% of the edge). After the edge, where the signal is the lowest, $10^6$ photons/pixel are necessary to reach the required SNR of $10^3$. The intensity ratio $I_{\text{before edge}}/I_{\text{after edge}}$ can reach 1000 in the most absorbing samples (absorption edge of 3 in the classical logarithmic representation). Thus, the required dynamic range does not exceed 12 bits. Nevertheless, the sensitivity range of the detector must extend from $10^6$ photons/pixel (the lowest signals after edge, strong absorption in sample and in sample environment) up to more than $10^{10}$ photons/pixel (for $I_0$ measurement in the same acquisition conditions than the absorption spectrum).

Linearity:
For EXAFS, linearity is an important parameter, in particular for dichroism experiments, and the detector should be linear in the whole dynamic range.

Flux on detector:
The flux on detector is expected to be of the same order of magnitude as it is now on ID24 or at maximum multiplied by 3. That is $10^8$ to $10^{13}$ photons/s on the whole detector, depending on the sample and sample environment absorption. Due to the energy profile given by the undulator, the intensity is not distributed uniformly on the detector: central pixels receive around 50 times more photons than border pixels.

It is worth notice that good quality EXAFS spectra can be obtained with 50 integrations of 100 ps each in the 4-bunch mode and that equivalent data are expected with integration times of few µs in the uniform mode.

Particular operating conditions:
Direct detection would improve the overall efficiency of the system. In that case, particular care should be taken concerning the radiation damage of the detector.

Required detector
The needed detector is a 1D device with short integration time and fast readout. The use of a 1D streak camera is envisaged in order to observe phenomena occurring in the duration of a photon bunch in stroboscopic mode.

Existing detectors
ID24 is currently using a setup composed of a scintillator, a diaphragm and a FReLoN CCD camera, reading only 32, 64 or 128 of the 2048 available lines.

Short term possibilities
A collaboration is envisaged with STFC in order to customise and use a fast Ge microstrip detector. In that case, the spatial resolution of the detector has to be increased for the highest part of the energy range: charge sharing seems to deteriorate the resulting energy resolution of the spectra.

Main required improvements
The main expected improvement concerns the detection speed (integration and readout times).
Other types of detectors

*TEXAS/EDXAS* requires also energy dispersive detector (see page 94).
Ultra-fast imaging

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Aim of the detection system
The aim of the detection system is to collect 2D photon images in order to record time-resolved tomography on absorbing samples (1mm – 1cm) during, for example, temperature or stress variations or chemical reactions.

Operating conditions and specifications

*Energy range:*
The energy mostly ranges from 30 to 80 keV in white beam.

*Integration time:*
Typical integration times are few ms. Enough photons will still be collected in experiments with integration times of 20 to 100 µs. Duty cycle has to be maximised.

*Energy resolution:*
Energy resolution is not needed.

*Spatial resolution:*
Typical spatial resolutions are 1 to 10 µm (FWHM) with field of view of 1 to 10 mm. A 1kx1k detector is suitable.

*Efficiency:*
Efficiency should be increased for the highest resolutions. Indeed, at 50 keV, the current efficiency of the scintillator (1 mm-thick LuAG:Ce) approaches 100% for the 14 µm pixel size but goes down to few percents when the smallest pixel size is used. Other materials permitting a gain in efficiency should present as fast response as current ones.

*Dynamic range:*
In order to go faster, a reduced dynamic range (such as 12 bits) is accepted.

*Linearity:*
Linearity is not a critical issue, provided that the reproducibility of the measurements is sufficient to make corrections of the deviations from linearity.
**Flux on detector:**
The expected flux on detector will reach $10^{15}$ photons/s/mm$^2$ (white beam).

**Particular operating conditions:**
In order to protect the detector from the direct beam, beam-stop and spherical mirrors in the Schwarzschild configuration are used to reflect the light from the scintillator into the optical sensor.

**Required detector**
The required detector is a fast 2D detector, with an adequate fast readout and data acquisition scheme.

**Existing detectors**
Fast CCDs in indirect illumination scheme (scintillator + mirrors) are currently used (Dalsa 1M60, Sarnoff CAM512). The purchase of a CMOS camera (Photron SA1, which have been tested successfully, or equivalent) is planned.

With the Photron SA1, no shutter was used because the data are transferred from the centre of the camera to the buffer parts in less than 50 µs (frame transfer mode with a 512x512 pixel ROI). In that case, the duty cycle approaches 100%.

Current CCD can generate up to 128 Mbytes/s of data. The CMOS camera will generate up to 10 Gbytes/s. This data will be stored on the detector (up to 32 Gbytes). Then the data (acquired in few seconds) will be transferred from the detector to a computer and this will take several hundreds of seconds. Thus the duty cycle will be 100% during the few seconds of one tomographic measurement, but much less if one considers the total acquisition process of several consecutive tomographic measurements.

**Short term possibilities**
Fast data transfer seems to be technologically possible. The adaptation of this technology directly on the detector has still to be done.

**Main required improvements**
The main expected improvement concerns the direct fast transfer of the data from the detector to the computer disks, without saving a huge amount of data in the detector before slow transfer.

**Other types of detectors**
*UPBL02* requires also other 2D detectors (see pages 44 and 71) and energy dispersive detector (see page 99).
*ID09HP, ID06LVP, ID15WB* project requires also another 2D detector (see page 44) and energy dispersive detector (see page 99).
*MIA* requires other 2D detectors (see pages 32, 36 and 39).
**High resolution – large dynamic range imaging**

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<td>High resolution 2D/3D imaging in parallel beam</td>
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<td>UPBL04: NINA <em>(ID22)</em></td>
<td>High resolution 2D/3D imaging in cone beam</td>
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</tbody>
</table>

**Aim of the detection system**

The aim of the detection system is to record 2D images of small objects with a spatial resolution of few microns, frequently in order to reconstruct tomographic representations or to visualise dynamic processes in 2D.

**Operating conditions and specifications**

*Energy range:*

For **NINA**, the energy ranges from **10 to 30 keV**. For **MIA**, it ranges from **6 to 60 keV**, with an expected extension up to 150 keV. In both cases, the beam is monochromatized through multilayered mirrors ($\Delta E/E=10^{-2}$). Some applications may use pink beam.

*Integration time:*

**MIA** will operate in continuous scanning mode as well as in step by step scanning mode. The typical exposure times for single images will be in many cases of the order of 1 ms and could reach **sub-ms** in the near future. It should be noticed that, in general, exposure times decrease drastically with increasing pixel size (higher flux per pixel and more efficient scintillators). Currently, the frame rate is more often limited either by the detector or by the shutter, rather than by the available photon flux. The availability of fast shuttering with deep millisecond opening times schemes becomes crucial. Electro-optical shutters or optical sensors with built-in electronic shutter control may become mandatory. But even in those cases, if the readout time is not negligible, it may be often required combined operation with fast mechanical shutters in order to reduce sample irradiation.
**NINA** will operate only in continuous mode and will privilege detection efficiency above speed. Nevertheless, any improvement of speed or duty cycle will be appreciated.

**Spatial resolution:**
For **MIA**, several spatial resolutions are needed, from 1 µm to 40 µm (FWHM of the PSF). A quick and easy way of changing magnification (zoom, revolving system, several detectors mounted on a movable stage…) is a very convenient feature. A goal not achieved today is to obtain the best possible resolution, even with lower efficiency.

For **NINA**, where the detector is placed in a diverging beam, the spatial resolution depends not only on the pixel size but also on the distance between sample and detector. The best configuration will privilege efficiency, the position of the detector permitting to reach the desired resolution: the pixel size will be chosen between 1 and 5 µm (PSF), with the highest efficiency of light conversion and collection. Currently, for 1 µm resolution, the efficiency is limited by the thickness of the scintillator and for 5 µm it is limited by the numerical aperture of the optics.

Given a certain spatial resolution, a widening of the field of view, compared to present situation, is expected. Going to 4kx4k pixels or even to 8kx8k is an interesting goal for this application. Large fields of view are needed when:
- sample cannot be cut (in tomography, imaging the whole sample is necessary);
- region of interest is not known at the beginning (it is less beam-time consuming to image the whole sample and find the ROI afterwards, than to search the ROI during the beam-time);
- statistical information is expected, such as porosity, transport phenomena…

Even if having more pixels implies longer readout times and acquisition of more projections, certain experiments will benefit from an increased number of pixels.

Image quality is important, particularly in tomography, where distortions corresponding to more than one pixel per line are not acceptable for tomography. The required large number of pixels may imply the development of specific optics to obtain desired image size and quality.

**Energy resolution:**
Currently, energy resolution is not used for this application and adequate detectors might not be available in the near future. Nevertheless, if detectors with both energy and spatial resolution become available, it would be interesting to use them for edge subtraction on images in pink or white beam.

**Efficiency:**
Efficiency should be increased with respect to currently achieved values, particularly for the resolutions between 2 and 7 µm. One goal could be to reach 50% DQE at 20 keV with 1 µm resolution (instead of the current 5-10% with GGG scintillator).

**Dynamic range:**
Large dynamic range is required in order to produce high quality images particularly in tomography experiments where the number of photons per pixel necessary to obtain a constant image quality increases linearly with N, where N is the number of pixels in the direction perpendicular to the rotation axis. This also assumes a linear increase in the number
of projections. A dynamic range larger than **13 bits** is needed for 2k pixels and it grows as $\sqrt{N}$ as the number of pixels increases.

The scintillator response should not degrade the required dynamic range (afterglow effects, emission from substrate).

**Linearity:**
The deviation from linearity should be less than **0.5%** on the whole dynamic range (current value is better than 2% with the FReLoN camera).

**Flux on detector:**
The flux for imaging is typically $10^{10}$ to $10^{13}$ photons/s/mm$^2$. The absolute maximum on detector is estimated to $10^{15}$ photons/s/mm$^2$ (flux obtained on ID22 with present configuration in pink beam – should be less on NINA, which will be longer).

**Other comments:**
**Data acquisition and storage:** Data correction and compression techniques built in the detector may be useful. Data compression may even present losses provided that they are well defined and adapted to quantitative volume imaging.

**Radiation hardness and stability:** In certain cases, the detectors will need to operate under heavy irradiation and heat load conditions. Both scintillators and optics may need to be stable and radiation tolerant, even compromising performance in some cases.

**Existing detectors**
ID19, ID22 and ID22NI are currently using FReLoN cameras with scintillators and several optical couplings giving pixel sizes from 0.2 µm to 30 µm.

**Required detector**
Required detector is a 2D sensor coupled via optical set-up to scintillator. The concept of FReLoN camera as general-purpose camera is extremely convenient: same imaging sensor for all optical configurations.

**Main required improvements**
The main expected improvements are efficiency, both in detection and time (read out as well as fast shuttering scheme to shorten the smallest possible exposure time). Then, the number of pixels, i.e. the field of view for a given spatial resolution, should be increased, preserving other specifications. Expected improvements are summarised below:

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<tr>
<th>Parameter</th>
<th>Short term</th>
<th>Medium term</th>
<th>Long term</th>
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<tr>
<td><strong>DQE</strong></td>
<td>Efficiency</td>
<td>Efficiency + Field of View</td>
<td>Efficiency + Field of View + Speed</td>
</tr>
<tr>
<td></td>
<td>50% at 20 keV with 1µm resolution</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Number of pixels</strong></td>
<td>4kx4k</td>
<td>8kx8k</td>
<td></td>
</tr>
<tr>
<td><strong>Dynamic range</strong></td>
<td>&gt; 13 bits (imposed by tomography needs)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Duty cycle</strong></td>
<td>&gt; 95% @ 100ms exposure → mechanical shutter impossible</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Maximum frame rate</strong></td>
<td>&gt; 1000 fps for 1kx1k pixels</td>
<td>&gt; 100 fps for 8kx8k pixels</td>
<td></td>
</tr>
</tbody>
</table>
Other types of detectors

*MIA* requires other 2D detectors (see pages 30, 36 and 39).
*NINA* requires also energy dispersive detector (see page 94) and a 2D detector for diffraction experiments (see page 48).
**Large field imaging**

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<td>UPBL05: MIA + Medical <em>(ID17 + ID19)</em></td>
<td>Large field imaging</td>
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</table>

**Aim of the detection system**

The aim of the detection system is to record 2D images of large samples, often in order to reconstruct tomographic representations. A particular case of this is the K-edge enhanced imaging, for which two lines are collected, imaging the same slice of the sample, at two different energies.

![Diagram of detection system](image)

**Operating conditions and specifications**

*Energy range:*
The energy ranges from **30 to 150 keV**, imaging applications associated with radiotherapy using 80 keV.

*Integration time:*
Two cases can be identified:

- **High resolution case:** For tomography on highly absorbing samples, exposure time is around **several hundreds of milliseconds**. In that case, the frame transfer mode can be used (the photons integrated during the 5 ms readout time can be neglected) and the current duty cycle is acceptable.

- **Fast case:** For the study of *in vivo*, moving specimens, a cycle of **few milliseconds (exposure + readout)** is targeted. In that case, it is necessary to increase the duty cycle of the detector,
even if it implies the use of a 1D detector or degradation of spatial resolution (as it is the case with the current Ge strip detector, that allows 0.1 ms integration time).

Energy resolution:
Energy resolution is not needed for this application.

Spatial resolution:
**High resolution case:** A pixel size of 20-30 µm is needed. The detector should be 2D but not necessarily square. A rectangular shape would be appreciated in order to exploit the beam shape (parallel beam of 2 x 16 cm² – HxV) without wasting time (readout of useless pixels). This permits to use the most homogeneous part of the beam in the vertical direction and to reduce the Compton scattering by illuminating only a thin slice of the sample. For these applications, a more polyvalent square detector could be used as well, even if only partly illuminated. A field of view of 2 x 16 cm² with 20 µm pixel size corresponds to **1kx8k pixels**. If necessary, this rectangular shape can be transferred to a square sensor through a fibre optics adapter (see [Bettuzzi et al., 2004]).

**Fast case:** For the applications where the dose limitation (and thus efficiency and speed) is more important than the resolution, a resolution of 100 µm could be accepted. If the only possibility to reach the needed speed and efficiency is to use a 1D detector, the second direction will be sacrificed.

The K-edge subtraction imaging technique, which uses 2 beams at 2 different energies converging on the same point of the sample, can be carried out either with two 1D detectors or with two series of lines of a 2D detector.

Efficiency:
In order to limit the dose on sample and if indirect detection scheme is kept, the scintillator efficiency (stopping power) at high energies has to be improved. One of the advantages of the strip detector is its high efficiency (100% at 20 keV and still 25% at 100 keV) compared to CCD based detectors (less than 40% at 20 keV with 40 µm-thick screen and less than 30% at 50 keV with 100 µm-thick screen [Coan et al., 2006]).

**Dynamic range:**
Dynamic range is very important in tomography. The number of photons per pixel necessary to obtain a constant image quality increases linearly with N, where N is the number of pixels in the horizontal direction (supposing the rotation axis vertical) and if the number of taken projections is also increased linearly with N. Moreover, in order to study very inhomogeneous samples or very absorbing ones without complex experimental tricks, a wide dynamic range is needed. Indeed, to obtain good quality tomographic scans, the specimen borders, and thus part of the direct beam, have to be recorded. In the case of very absorbing samples, the direct beam intensity is chosen very high. If the detection dynamic range is too small, the direct beam saturates the detector. A fastidious trick consists in surrounding the sample with aluminium in order to decrease the intensity of the beam around the sample. To avoid these difficulties, a dynamic range of at least **16 bits** would be desirable.

**Linearity:**
Linearity is critical for quantitative analysis on biomedical applications, and it corresponds to higher data quality in the case of non-quantitative imaging.
Flux on detector:
The flux on the detector is expected to be between $10^8$ and $10^{10}$ photons/s/mm$^2$, depending on the energy. These values are smaller than the flux for other imaging beamlines because of two reasons: ID17 uses only one wiggler and the photons are spread over a larger beam.

Particular operating conditions:
Due to the use of high energy photons, radiation damage generates a very rapid blackening of the taper. Better radiation hardness would be appreciated.

Required detector
Required detector is a large 2D rectangular detector, that can be efficiently used at high energy.

Existing detectors
ID17 is currently using a FReLoN 2kx2k, with fibre optic taper and scintillator. For the applications requiring less spatial resolution but more efficiency and speed, a Ge 2-strip detector, with 350 µm pitch and 10 mm width, is used.

Short term possibilities
Structured CsI scintillators will be tested. The use of a FReLoN 4M instead of current FReLoN 2k will improve both dynamic range (by a factor 1.5) and quantum efficiency (65% efficiency at the Gadox emission wavelengths instead of 35%). Nevertheless, this will not directly permit to reduce the dose on the sample because in the case of taper coupling, where the light collection yield is high, the signal to noise ratio depends much more on the absorption coefficient of the scintillator than on the quantum efficiency (see DQE formula in [Koch et al., 1998]). This means that even if the total yield of the detector is increased, the SNR will not be proportionally improved.

Main required improvements
The main expected improvements concern the efficiency and the field of view at constant or better spatial resolution. Radiation hardness of optical couplings has to be improved.

Other types of detectors
MIA requires other 2D detectors (see pages 30, 32 and 39).
Imaging combined with diffraction

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<tr>
<td>UPBL05: MIA (ID19)</td>
<td>Imaging combined with diffraction</td>
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**Aim of the detection system**

The aim of the experiment is to reconstruct tomographic representations of multi-grain crystalline samples (light metal alloys, ice, NaCl, ceramics, semiconductors,...). To do this, the sample is rotated step by step as in other tomographic experiments but more information is acquired: the direct absorption image of the sample is recorded in the centre of the sensor and the images of the diffracted spots appearing each time a grain has the proper orientation to diffract are recorded in the outer part of the sensor.

---

**Operating conditions and specifications**

*Energy range:*
The energy ranges from **15 to 50 keV**.

*Integration time:*
Exposure time ranges between **0.1 and 10 s**, depending on the hosting beamline flux. If the number of pixels is multiplied by 4 (4kx4k instead of 2kx2k), a readout time multiplied by 4 should be acceptable.

The frame transfer readout mode can be used without X-ray shutter provided that the integration time is much longer than the readout time (by at least a factor of ten). In the full frame mode, the readout time should not exceed 500 ms, so that series of tomographic scans (with stress application, heating… between scans) could be recorded in a reasonable amount of time.

For the shortest exposure times, avoiding the use of a mechanical shutter could be useful.

*Energy resolution:*
Energy resolution is not currently used. It could be used in order to index the diffraction spots if the experiment was carried out in white beam, which has been envisaged. Nevertheless, it should not be detrimental to spatial resolution, since spatial resolution is needed for the imaging part of the study.
**Spatial resolution:**
A 2D detector is necessary to record both the direct image and the diffracted spots in all the directions perpendicular to the beam (a maximum of spots is necessary to reconstruct the shape of the grains, one quadrant is not enough).
Spatial resolution is used both for direct imaging of the sample and localisation of the diffraction spots around the image (centroid, area, intensity,…). A pixel size of 1 to 3 µm is required for imaging. A large field of view is needed to collect the widest possible part of the diffraction pattern. The image is recorded in parallel beam but the distance between the sample and the detector can be varied in order to adapt the solid angle of collection of the diffracted signal. A field of view of 4kx4k pixels (that is 4 x 4 mm² with 1 µm pixel size) would be appreciated. Since the symmetrical diffraction spots (Friedel pairs) are studied, the useful field of view is square and not rectangular.

**Efficiency:**
Efficiency should be improved, particularly at high energy. The problem is that the diffracted beams do not reach the scintillator normally to the surface but with an angle that broadens the spot. Thus the scintillator should be as thin as possible, even more than for other high resolution applications.

**Dynamic range:**
Since the number of photons per pixel is approximately 10 to 100 times higher in the sample image than in the diffracted spots, dynamic range is an important issue. It should be at least as it is now: 14 bits.

**Linearity:**
Current linearity obtained with the FReLoN camera is satisfactory.

**Flux on detector:**
Flux will be highly dependant on the beamline hosting this detector. It will be at least comparable to the one currently obtained at ID19, that is between $10^8$ and $10^9$ photons/s/mm². Fluxes foreseen on MIA are $10^{10}$ to $10^{13}$ photons/s/mm² for the transmitted beam. Thus, one can foresee $10^8$ to $10^{11}$ photons/s/mm² for the diffracted spots.

**Particular operating conditions:**
Since this set-up will be installed on different beamlines, lightness and ease of installation on any experimental environment would be useful. It should be thought, for example, to separate even more than in the current FReLoN camera the cooled sensor head from the rest of the detector.

**Required detector**
The required detector is a high resolution 2D detector.

**Existing detectors**
For this application, FReLoN detectors (Atmel 2k14 and Kodak 4M) are currently used.

**Short term possibilities**
A 4kx4k sensor could be used in frame transfer mode to increase the duty cycle.

**Main required improvements**
The main expected improvements concern the efficiency and the field of view.
Other types of detectors

*MIA* requires other 2D detectors (see pages 30, 32 and 36).
Near field scattering

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<td>Near Field Scattering</td>
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**Aim of the detection system**

The aim of the detection system is to record near-field speckle for the analysis of scattered field (NFS: near field scattering).

**Operating conditions and specifications**

*Energy range:*
The experiments are carried out using a fixed energy around **12.4 keV** (corresponding to a wavelength of 0.1 nm).

*Integration time:*
NFS signals contain both static and dynamic information. In order to calculate the scattered field-field autocorrelation function, **millisecond** time resolution is required.

*Energy resolution:*
Energy resolution is not needed for near field scattering.

*Spatial resolution:*
A detector with **1 µm** resolution and a **few hundreds of µm field of view** would be convenient for near field scattering since speckles are heterodyned with the strong transmitted beam: the scattered signal interferes with the transmitted beam to give the desired speckles, thus the image is not larger than the incident beam.

*Efficiency:*
Since samples are radiation sensitive, the detector must have good sensitivity to use the lowest possible dose on the sample.

*Dynamic range:*
Near field scattering implies to measure small intensity fluctuations lying above the strong transmitted beam. Thus, the detector should be able to measure high photon fluxes with very low noise level to record speckles with high contrast. The ability to detect fluctuations of 1 over 10^6 would enable the study of dilute samples.
Linearity:
1% deviation from linearity will be sufficient since only the intensity fluctuations are recorded.

Flux on detector:
The direct transmitted beam is recorded and it is of the order of $10^{14}$ photons/s, that is around $10^8$ photons/s/pixel if they are spread over a 1kx1k sensor.

Particular operating conditions:
The detector will be placed very close to the sample (a few mm to a cm).

Required detector
2D detector with high spatial resolution and high dynamic range is required.

Existing detectors
A FReLoN 2000 with 40x microscope objective is currently used at ID02 for this application.

Main required improvements
Spatial resolution and point spread function should be improved. It is desirable to have a direct conversion detector in order to have a flat spatial frequency response. Improvements in terms of the dynamic range and time resolution are required.

Other types of detectors
SAXS beamline requires also other 2D detectors (see page 73 and 76).
High energy diffraction

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<td>PMF (ID06)</td>
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</tbody>
</table>

**Aim of the detection system**

The aim of the detection system is to count photons in order to record diffraction patterns and study their evolution during solid state reactions, change of pressure, change of temperature, eventually faster reactions…

![Diagram of monochromatic beam, sample, and detector.](image)

**Operating conditions and specifications**

*Energy range:*

The energy range addressed by this description goes from 25 to 125 keV with particularities for each beamline:

- *MatSci* covers the entire range, but operates most often below 100 keV;
- *PMF* goes up to 60 keV and works most frequently between 30 and 40 keV;
- *ID09HP, ID06LVP* and *HP* work between 30 and 80 keV, but mainly at 30 keV (about 70% of beamtime);
- *UPBL02* works between 80 and 120 keV.

*Integration time:*

Applications can range from static characterisation, with exposure time of **one to several seconds**, to time-resolved experiments (chemical reactions, evolution during heating, …), with exposure time of 1 to 100 ms. In those cases, shutterless operation may be necessary.

Another type of applications (diffraction in pulsed magnetic fields in order to operate in stroboscopic mode, powder diffraction using the time structure of the electron beam at *UPBL02*) would require microsecond or sub-microsecond integration time.

Finally, diffraction in pulsed magnetic fields could be carried out in “burst mode”, that is reading around 1000 single frames with an exposure time of 1 ms per frame as quickly as possible and having, after the burst, several minutes for data storage.
Energy resolution:
Energy discrimination can be useful for fluorescence background suppression for ID09HP, ID06LVP, MatSci and PMF. This implies a resolution about 1 keV. All the beamlines would be highly interested in Compton background suppression, but this requires resolution better than 100 eV, which will most probably remain impossible in the coming years.

Spatial resolution:
In diffraction experiments, the sample to detector distance can be adjusted in order to obtain the desired resolution. Pixel size between 50 and 200 µm should be convenient, particularly if the PSF is decreased compared to current values (obtained with fluorescent screens). The detector size should be at least 300x300 mm². Indeed, the complex sample environment, in particular for extreme condition experiments (large press, laser heating, cryostat…), imposes a minimum sample to detector distance of about 250 mm and thus a minimum detector area. Moreover, placing the detector farther decreases the influence of Compton scattering (repartition of the same scattered intensity on a larger solid angle, whereas the diffracted beam is only weakly divergent). With small pixels, one has to put the detector near the sample and thus reduce the size of the beam to keep the resolution. This implies a loss of photons. Moreover, if the detector is put closer, it is more exposed to perturbation effects due to the sample environment (magnetic field…).
In order to reach ms time resolution, smaller detectors could be used: 100x100 mm² would permit to collect 1 or 2 reflections in an image; a 1D detector could also be envisaged for some applications (fast powder diffraction experiments).
Dead areas would be manageable if they do not exceed 5% of the total area and especially if their location is compatible with the symmetries of the diffraction patterns.
The possibility of doing binning in the outer part of the detector and not in the centre could be interesting since the diffraction peaks broaden with increasing Bragg angles. Indeed, for thick samples, a broadening appears at wide angles, where the diffracted beam coming from the front of the sample does not reach the detector at the same position than the one coming from the back (projection error). The broadening at wide angles can also be due to the strains in the sample and to the beam characteristics (divergence…). This different binning system would be interesting only if it allows to collect the data much faster, or if the gain in data storage space is significant.

Efficiency:
Current area detectors present around 10% efficiency at the 60 keV. The improvement of the efficiency is thus the point where most could be gained.

Dynamic range:
Intensity can vary from 0.1 photon/s/pixel to 10^{12} photons/s/pixel. A large dynamic range is thus needed even if it is always possible to attenuate the beam and take several images with different attenuations: there is no upper limit on what dynamic range would be useful.
A detector with different gains on each pixel could permit to measure with similar accuracy high and low intensities coming at the same time on different parts of the detector.

Linearity:
Linearity is very important for accurate structure refinements. Linearity within 0.1% to 1% after corrections is required on a wide intensity range, which will define the usable dynamic range of the detector.
**Flux on detector:**
The flux can reach $10^{12}$ photons/s/pixel (with 100x100 $\mu$m$^2$ pixels) in few pixels and is much less in the other pixels: possibly 0.1 photon/s/pixel.

**Particular operating conditions:**
The sample can be submitted to high pressure, high or low temperatures, electric or magnetic fields but this should have no effect on the detector itself, except in the case of PMF, where the stray magnetic fields can reach 0.1 T. If the pixel size is smaller, the detector will be placed closer to the sample and will be more exposed to the stray fields.

Intense diffraction peaks can reach the detector either when carrying out single crystal diffraction experiments or even in high pressure experiments due to the use of diamond windows. Thus, the radiation damage risk should be estimated. Nevertheless, current detectors have never been significantly damaged by irradiation, probably due to the dose reduction at high energy linked to the absorption drop.

**Required detector**
The required detector is a large 2D detector, with good efficiency at high energy and improved readout time.

**Existing detectors**
ID06, ID09 and ID27 currently use Mar345 image plate, which fulfils quite well the needs considering the existing available technologies. Main drawbacks are the very long readout time (2 minutes) as well as high background and vibrations. ID27 also uses Mar165 CCD, which is faster but has still a long readout time (4 seconds), low sensitivity at high energy and small detecting area.

ID11 uses FReLoN 2k and 4M cameras and would prefer to use a photon counting detector in order to avoid corrections for the gain of the system, perform shutterless experiments and to have better dynamic range.

ID15 uses a Pixium flat panel, which appears noisier and slower than desired for their applications.

**Short term possibilities**
The Mar555 a-Se flat panel would permit significant progresses in terms of size and efficiency. A Pilatus type detector, adapted to high energy with high Z sensor, could be promising. Medium term solution could also consist in tiling CCD sensors (such as Rigaku Satrun A200 or Quantum 315) with high-Z screens.

**Main required improvements**
The main expected improvement concerns efficiency, where there is space to gain one order of magnitude. Then, improvements on number of pixels, speed and noise are also desired. Integration of the detector on the beamline (hardware and software…) is an important issue.

**Other types of detectors**
UPBL02 requires also other 2D detectors (see pages 30 and 71) and energy dispersive detector (see page 99).

**ID09HP, ID06LVP, ID15WB** project requires also another 2D detector (see page 30) and energy dispersive detector (see page 99).

**MatSci** uses also a combination of three 2D detectors in order to reconstruct an image of the structure of the sample (grains, strains…). This system combines two detectors, each one
associated with a thin phosphor screen and a semi-transparent mirror, placed close to the sample and recording diffraction images at two different distances with another detector placed far from the sample and recording the precise position of the Bragg peaks. The two first detectors are set at 90 degrees, so that the beam can go through the semi-transparent mirrors to reach the down-stream detector. The last one is set in-line with the beam. This system is being commissioned and no major evolution is planed for the coming years.

**PMF** requires also point detectors for XAS (see page 19), other 2D detectors for diffraction (see page 50 and 59) and energy dispersive detector (see page 94).
Standard diffraction and 2D/3D diffraction - mapping

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<td>Diffraction and diffraction mapping (2D/3D)</td>
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<td>UPBL11: TEXAS/EXAFS (BM29)</td>
<td>Diffraction</td>
</tr>
</tbody>
</table>

Aim of the detection system

The aim of the detection system is to record 2D or 3D diffraction maps in order to reconstruct images of polycrystalline samples and to measure diffraction patterns as complementary information to the main technique of the beamline (absorption spectroscopy, imaging) on powders or single crystals.

Operating conditions and specifications

Energy range:
The energy ranges from 15 to 60 keV. It is a monochromatic beam on both TEXAS/EXAFS and NINA, which will carry out diffraction only on the “NA” branch (Nano-Analysis) of the beamline.

Integration time:
Integration times will range between tens of milliseconds and few seconds. One goal is to follow chemical reactions or pressure evolution at the same time by diffraction and spectroscopy, measuring one diffraction pattern at the end of each absorption spectrum. This requires integration and readout times compatible with the kinetics of the reaction. Moreover, in order to perform 2D and 3D mapping efficiently, the readout time must be smaller or at least not longer than the integration time.

Energy resolution:
Energy resolution is not needed for this application.

Spatial resolution:
The sample-to-detector distance can be adapted to obtain the desired angular resolution. Pixel size between 50 and 150 μm and 2kx2k pixels would be convenient. An example, a 2D detector with 2kx2k pixels of 100 μm placed at 20 cm from the sample would let record reflections up to θ=25 degrees with a resolution of about 1 mrad, which is similar to what is currently obtained.
Efficiency:
In order to reduce the exposure time (to follow the pressure evolution and chemical reactions or to obtain 3D data sets in reasonable time, compared e.g. to the stability of the beam), the efficiency should be optimized.

Dynamic range:
Current dynamic range (14 bits) seems sufficient.

Linearity:
No major improvement is required on linearity.

Flux on detector:
At NINA, typical flux on detector will be around $10^8$ photons/s on the whole detector, varying from few photons/s/pixel to $10^4$ photons/s/pixel. At TEXAS/EXAFS, using a bending magnet, the flux should not be higher.

Required detector
The required detector is a 2D detector with high sensitivity and fast readout.

Existing detectors
BM29 is using a Mar345 image plate detector.
ID22 is using a FReLoN (Atmel) camera with taper.

Main required improvements
The main expected improvement concerns the reduction of the readout time.

Other types of detectors
NINA requires also a 2D detector for imaging (see page 32) and energy dispersive detector (see page 94).
TEXAS/EXAFS requires also point detectors (see page 19) and energy dispersive detector (see page 94).
Powder diffraction in pulsed magnetic fields

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Aim of the detection system
The aim of the detection system is to collect photons in order to record a diffraction pattern on powder samples. It is the third priority of the beamline, after single crystal diffraction and high energy diffraction. It can also be used by the MagScat beamline.

Operating conditions and specifications

Energy range:
The energy ranges from 15 to 30 keV.

Integration time:
The magnetic field pulse lasts around 30 ms and is repeated each 1 to 5 minutes. The integration time should be 1 ms during the pulse, with few minutes of pause to save the data.

Energy resolution:
Energy resolution is not needed.

Spatial resolution:
Spatial resolution depends on the size of the active area and of the distance to sample. In order to probe powder and not few single crystals, the beam size is larger than 200 µm. In that configuration, one can obtain good spatial resolution only by setting the detector far from the sample: at least at 2 m in that case. Consequently, the detector should have an active area of 350x350 mm$^2$ to 500x500 mm$^2$ with pixels not larger than 100 to 300 µm.

Dynamic range:
A dynamic range similar or better than that of the current detector is required: 16 bits or better.

Flux on detector:
The expected flux on detector ranges between $10^3$ and $10^6$ photons/s/pixel.
Particular operating conditions:
The detector will be operated near high magnetic fields (30 T) that may generate stray fields up to 0.1 T.

Required detector
The required detector is a large and fast 2D detector.

Existing detectors
ID06 is currently using a MAR345 image plate detector.

Main required improvements
The main expected improvement is the ability to acquire several spectra per magnetic field pulse. Furthermore, a detector presenting larger area but conserving other specifications will allow collecting larger diffraction angles, thus improving the resolution.

Other types of detectors
PMF requires also transmission mode detection (see page 19), other 2D detectors for diffraction (see pages 44 and 59) and energy dispersive detector (see page 94).
Soft X-ray emission spectroscopy

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**Aim of the detection system**

The aim of the detection system is to count photons after grazing incidence analysis on a grating in order to obtain emission spectra. This is the second most used technique on the beamline (after absorption spectroscopy).

**Operating conditions and specifications**

*Energy range:*
The incident energy ranges from 0.5 to 2 keV.

*Integration time:*
Typical integration times are several seconds.

*Energy and position resolution:*
The energy resolution is given by the gratings and can only be exploited with the best achievable spatial resolution on detector. The total resolving power of the beamline is around 30 000: the spatial resolution of the detector must give the possibility to reach an energy resolution better than 30 eV in the dispersion direction. This implies a spatial resolution better than 10 µm. In the perpendicular direction, the spatial resolution also improves the energy resolution compared to e.g. a strip detector, by giving the possibility to correct from aberrations and tilts. The grating distributes the photons on a large solid angle, thus, the widest the detector active area, the best, provided that the readout time remains reasonable. Energy resolution is not needed for the detector itself.

*Efficiency:*
The efficiency of the overall system has to compensate the small number of collected photons.
Dynamic range:
Since the count rate is low, the dark current is expected to be minimised: less than 1 count per second on the whole detector. The readout noise has also to be reduced. Currently, to limit the readout noise, the slowest readout rate is used: readout takes around 1 minute per frame.

Flux on detector:
The flux is expected to be similar to the current one (few photons/s on the whole detector). Indeed, each possible gain in beam intensity is sacrificed in order to gain energy resolution.

Particular experimental conditions:
The detector is operated in ultra-high vacuum. Current compatibility with UHV has to be improved.

Required detectors
The required detector is a 2D fast readout highly sensitive detector in a direct X-ray illumination configuration that can be operated in UHV. It has to be noticed that current camera is not really UHV compatible: it is not bakeable, but with the liquid nitrogen cooling and the fact that it is located quite far from the grating, it is possible to preserve the UHV in the sample chamber.

Existing detector
The current detector is a Roper CCD, 2kx2k, with 13 µm pixel size, LN$_2$ cooled. It is tilted along the dispersion direction in order to get better resolution (even if this implies a loss of energy spectrum width).

Short term possibilities
Andor and Princeton have been contacted to provide a detector with 3 buttable CCDs. This gain of factor 3 in detection area would be used either
- in the direction perpendicular to the dispersion direction: in order to increase the solid angle coverage, conserving the current resolution and spectrum width in the dispersion direction
- in the dispersive direction: in the case the spectrometer is larger, leading to more energy-resolved spectra, dispersed in a larger range.

Main required improvements
The main requirement concerns the total efficiency (intrinsic efficiency, faster readout with same noise and solid angle coverage) while keeping the spatial resolution in the dispersion direction.

Other types of detectors
$UPBL07$ requires also point detectors (see page 23), other 2D detectors (see page 54) and energy dispersive detector (see page 94). The needs for electron / spin detectors are not detailed in this report.
Aim of the detection system
This section gathers several experiments carried out in different geometries:
- recording holographic images formed by the interference of the direct coherent beam defined by a pinhole and the beam scattered from the sample (e.g. magnetic multilayer);
- recording resonant magnetic scattering using coherent beam in reflection geometry;
- collecting diffraction patterns from magnetic structures.
These techniques are not the main priority of the beamline, but the possibility to use the coherence of the beam will be preserved as a promising technique.

Operating conditions and specifications
Energy range:
The energy ranges from 0.4 to 2 keV.

Integration time:
Typical integration times are several hundreds of ms.

Energy and position resolution:
Energy resolution is not needed for this application.
Spatial resolution around 10 to 20 µm would be convenient. Nevertheless, part of the magnetic diffraction experiments will require a point detector coupled with a polarization analyser, as it is the case for the MagScat beamline (cf. page 14).

Efficiency:
Efficiency is not the critical point for this application.

Dynamic range:
The effective dynamic range can be improved by accumulating several images.

Flux on detector:
The flux is expected to reach at maximum $10^6$ photons/s/pixel but it varies a lot between pixels and will be weaker in coherent scattering than in magnetic diffraction.

Particular experimental conditions:
The detector is operated in ultra-high vacuum. For magnetic diffraction, it is mounted on a 0-20 arm inside the UHV vessel. Current compatibility with UHV has to be improved.

Required detectors
The required detector is a 2D detector in a direct X-ray illumination configuration that can be operated in UHV and withstand the direct beam.

Existing detectors
For coherent scattering the current detector is a Princeton CCD, 24 x 24 mm$^2$, that has to be protected from the direct beam.
For magnetic diffraction, the current detector is a Roper CCD, 2kx2k, with 20 µm pixel size, water cooled. It is easily damaged by the direct beam and not UHV compatible (only $10^{-7}$ mbar).

Short term possibilities
The use of CCD cameras should continue for the low count rate applications. For the higher count rates, the use of Si diode arrays or APD arrays is envisaged. APD detectors for soft X-rays have been investigated at Brookhaven NSLS.

Main required improvements
Detectors conceived for low energies and UHV similar to existing pixel detectors would be considered as a great improvement.

Other types of detectors
UPBL07 requires also point detectors (see page 23), other 2D detectors (see page 52) and energy dispersive detector (see page 94). The needs for electron / spin detectors are not detailed in this report.
Anomalous and microfocus diffraction on proteins

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Aim of the detection system

The aim of the detection system is to collect photons in order to record diffraction patterns on proteins (MAD or microfocus techniques).

![Diagram of diffraction setup](image)

Operating conditions and specifications

**Energy range:**
The energy ranges from 5 to 25 keV.

**Integration time:**
Typical integration times range from 50 ms to 30 s per frame. A major problem in protein crystallography is the radiation damage, that does not only increase with increasing dose but also with time (radicals migration in sample). The readout time has thus to be shortened in order to reduce the effects of the radiation damages. Moreover, when the readout time cannot be neglected compared to the acquisition time, synchronization problems appear between the shutter, the detector and the sample rotation. Indeed, the sample is rotated at constant speed during the image acquisition (over approximately one degree) and must be stopped, repositioned and started again to reach constant speed at correct angles (the next one degree) for the next image acquisition.

**Energy resolution:**
Energy resolution is not needed for this application.

**Spatial resolution:**
100 µm spatial resolution is required. It should be enough to separate the peaks, even for large unit cells (up to 500x500x500 Å³) where the peaks are very close. Better Point Spread Function would be preferred to smaller pixel size (big images with too many pixels are not desired because of the huge amount of data that have to be stored). This could be obtained by pixel counting detectors better than by CCDs. The detector has to be large (more than 300x300 mm²) because the information concerning the protein chains is diffracted at large angles and because the detector is placed quite far from the sample (80 to 600 mm) in order to maximise the signal to noise ratio. Indeed, the diffracted beam is parallel whereas the background (scattering from the glassy parts of the
frozen sample) is distributed over a large solid angle and thus is “diluted” on the whole detection surface. Moreover, in order to increase the intensity of the diffraction pattern, one can decrease the incident photon energy (increase the wavelength, that is then closer to the lattice plane spacing). Increasing the wavelength will increase the $\theta$ angles, and thus the surface to be collected.

The detection has to be as homogeneous as possible on the whole surface and as stable as possible in order to compare peak intensities appearing at different positions at different times.

Dead areas between modules are taken into account in the calculated data collection strategy, so that complete data can be acquired despite the dead areas.

**Efficiency:**
An improvement of the global efficiency of the system would permit to reduce integration times and thus radiation damage. Nevertheless, the DQE is already higher than 80% between 8 and 14 keV on the currently used ADSC detectors.

**Dynamic range:**
In MX experiments, spots appearing at both small angle (crystal cell description) and wide angle (protein chain structure) are interesting. The intensity of the wide angle reflections is much weaker than that at small angles. In order to collect efficiently the whole pattern in a single shot, a dynamic range larger than 16 bits is required. When the difference between weak and strong peaks is too large, the pattern is collected in two shots: one short exposure to avoid the saturation in the centre of the pattern and one long exposure to have enough intensity at wide angles. This situation currently happens for most of the experiments.

In order to detect small differences on weak signals (MAD experiments) or to measure correct intensity of weak spots (very small crystals – 20 to 100 µm –, large angles), the signal to noise ratio has to be maximised.

**Linearity:**
In order to perform MAD experiments where the difference between intensities of interest (Friedel pairs) is smaller than 5%, the detection has to be as linear as possible on the whole dynamic range.

**Flux on detector:**
Foreseen photon fluxes delivered by the beamlines should not differ strongly from current situation. Depending on the beamline, the flux reaching the sample varies from $10^{11}$ to $10^{13}$ photons/s (corresponding to $10^{13}$ to $10^{15}$ photons/s/mm$^2$ on the sample). The diffraction pattern is formed of 1000 to 2000 peaks with an integrated intensity of at maximum 5% of the incident flux, depending on the sample, that is at maximum $5\times10^{11}$ photons/s on the whole detector distributed among intense and weak peaks. An estimation made on a typical sample of trypsine gives the following figures: the integrated intensity collected on the ADSC Quantum 315r is about $10^9$ photons/s while the intensity integrated over the diffraction peaks (about 1000) is about $10^7$ photons/s. The whole dynamic range of the detector (16 bits) is used, some pixels being saturated whereas the smallest peaks appears as only few tens of counts.

**Particular operating conditions:**
The detector has to be placed in a constrained environment, with nitrogen cryocooler stream on the sample.
In order to decrease the absorption in the air and thus to be able to record weaker signals, the possibility of placing the sample and the detector in vacuum is studied.

**Required detector**
The required detector is a large 2D detector with high dynamic range, high sensitivity, fast readout and good homogeneity and stability.

**Existing detectors**
All the MX beamlines are using scintillator screen – fibre optic bundle – CCD based detector systems for their diffraction experiments. ID14-1 is using an ADSC Quantum 210r (210x210mm$^2$; 2x2 CCD chips with fibre optic taper demagnification). ID14-2 is using an ADSC Quantum 4r (180x180mm$^2$; 2x2 CCD chips with fibre optic taper demagnification). ID23-2 is using a more recent Mar225, presenting better dynamic range. ID23-1 and ID29 are using the more recent ADSC Quantum 315r (315x315mm$^2$; 3x3 CCD chips with fibre optic taper demagnification) with better dynamic range and shorter readout times.

**Short term possibilities**
The ADSC Quantum 315r will continue to be used. A Pilatus 6M has been tested with success and should be the good candidate to replace older detectors. It should be noticed that the huge amount of data generated by Pilatus during an experiment starts to be the limiting factor.

**Main required improvements**
The main expected improvement concerns the dynamic range and the readout speed.

**Other types of detectors**
MX beamlines require also 2D detectors for SAXS experiments (see page 84) and energy dispersive detector (see page 94).
**Single crystal diffraction in pulsed magnetic fields**

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**Aim of the detection system**

The aim of the detection system is to collect photons in order to record a diffraction pattern on single crystals. This would be the main experiment on **PMF**.

**Operating conditions and specifications**

*Energy range:*  
The energy ranges from **3.7 to 25 keV**.

*Integration time:*  
The magnetic field pulse lasts around 30 ms and is repeated each 1 to 5 minutes. The integration time should be **1 ms** during the pulse, *with few minutes of pause to save the data*.  

*Energy resolution:*  
Energy resolution would be used for background reduction, using upper and lower thresholds.

*Spatial resolution:*  
Spatial resolution depends on the size of the active area and of the distance to sample: in the nearest position strategy, the smallest possible area would be **25x25 mm²**, with pixels of **50 µm**. Larger detector with larger pixels should also be convenient.

*Dynamic range:*  
In order to collect the lowest signals, detector noise should be minimised. Energy discrimination could also be useful for this.

*Flux on detector:*  
The expected flux on detector ranges from **10 to 10⁶ photons/s/pixel**. A correct signal is obtained with 1000 counts in 1 ms. For smaller count rates, accumulation on successive pulses is performed.
Particular operating conditions:
The detector will be operated near high magnetic fields (30 T) that may generate stray fields up to 0.1 T.

Required detector
The required detector is a 2D counting detector with very low noise and short integration time.

Existing detectors
This application is not yet tested but will be first performed with an APD point detector with slits.

Short term possibilities
The use of a MEDIPIX detector is envisaged.

Main required improvements
The main expected improvement concerns the optimisation of the triplet {high readout speed – small enough pixels – large enough area}.

Other types of detectors
PMF requires also transmission mode detection (see page 19), other 2D detectors for diffraction (see page 44 and 50) and energy dispersive detector (see page 94).
Inelastic X-ray spectroscopy

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<td>XAS-XES (ID26)</td>
<td>Resonant inelastic spectroscopy</td>
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Aim of the detection system
The aim of the detection system is to count photons after crystal analysers in order to obtain inelastic scattering spectra.

Operating conditions and specifications

Energy range:
The energy ranges from 2.4 to 27 keV:
- from 15 to 26 keV, for phonon spectroscopy (IXS-PH)
- from 5 to 14 keV (or at least 6 to 12), for electronic excitation (INES)
- from 2.4 to 27 keV for XAS-XES.

Integration time:
On IXS-PH and INES, the number of “interesting” photons is low, thus acquisitions are long: the integration time is several seconds. On XAS-XES, integration times range from few ms to few seconds.

Energy and position resolution:
The energy resolution is determined by the analyser. Nevertheless, energy resolution of few hundreds eV would give the possibility to suppress background.
Spatial resolution of the detector will improve the energy resolution of the whole detection system, by measuring the spatial dispersion of the photons arriving on the detector after selection by the analyser. On the other direction, it gives the possibility to select only the signal coming from the sample, and not from the environment. It also allows to collect the signals coming from several crystal analysers on different areas of the detector.
Spatial resolution of at least 50 µm is needed for INES and XAS-XES, where the detector is close to the analyser, and at least 150 µm for IXS-PH, where the expected energy resolution is better and the distance between detector and analyser greater – about 7 m.
Efficiency:
This is the most critical point since, as said before, the number of “interesting” photons is low. For the high energy part, the possibility of using new CdZnTe detectors is studied in addition to the use of thicker chips when available.

Flux on detector:
At IXS-PH and INES, the expected flux on the detector ranges between $10^2$ and $10^3$ photons/s. At XAS-XES, the flux can reach several $10^6$ photons/s.

Required detector
The expected detector is a counting detector with maximal detection quantum efficiency, possibility of background suppression and spatial resolution of at least 50 µm (for INES and XAS-XES) and at least 150 µm (for IXS-PH). Pixel detector such as MAXIPIX or eventually APD array detector could fulfil these requirements.

Existing detectors
For phonon spectroscopy (15 – 26 keV):
ID16 and ID28 are using a monolithic 5-element 1mm-thick Si diode in counting mode (3x8 mm² each, made by Canberra). It has a very low electronic background of typically 1 to 3 counts per hour. The diode is tilted by 20 degrees to have 3-4 mm effective thickness and thus total absorption in the higher part of the energy range.

For electronic excitation (5 – 14 keV):
ID16 is using MAXIPIX and APDs. The current MAXIPIX pixel size of 55 µm is convenient but should not be bigger. Indeed, pixels with small vertical dimension are required in order to exploit at best the vertically dispersed X-ray energy.
ID26 is using APD detectors and is testing a Ketek® SDD detector, with large area accepting the whole beam (3x15 mm on sample).
A strip detector has been tested (Hermes detector from MERIX beamline at Advanced Photon Source). It gave better results than MAXIPIX at low energies because of lower noise (less charge sharing and water cooling, resulting in better energy resolution and less noise). Nevertheless, the spatial resolution is lower and the second dimension resolution is missing (impossibility of selecting signal coming from various crystal analysers). Moreover, beryllium window decreases the efficiency for the lower energies.

Short term possibilities
For phonon spectroscopy (15 – 26 keV):
The use of a MAXIPIX detector can bring the spatial resolution required to improve the energy resolution of the system. In order to preserve the absorption efficiency at high energy, the detector should be tilted (in the direction where the spatial resolution is not used). Tilting the pixel detector horizontally can increase the efficiency but it may require quite precise positioning if one wants to preserve the exploitation of the vertical energy dispersion of the X-rays. When available, GaAs sensor prototypes should avoid the tilting strategy.

For electronic excitation (5 – 14 keV):
In the lower energy range (5-6 keV), MAXIPIX presents strong efficiency loss compared to APDs. Low efficiency is attributed to charge sharing. Another chipboard with higher grade
chip should be tested. Timepix, which has better low energy response, is also proposed for the future. 

*XAS-XES* would primarily use thicker APDs before commissioning 2D detectors. The use of strip detectors is also envisaged for both *XAS-XES* and *INES* beamlines.

**Main required improvements**

The main expected improvement is better efficiency of detection on the whole energy range.
## Powder diffraction

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### Aim of the detection system

The aim of the detection system is to count photons after crystal analysers in order to obtain a powder diffraction spectrum that can be refined, for instance, via Rietveld methods. Two strategies are envisaged: either recording the spectrum step by step, with very good angular resolution, either recording the spectrum in one shot, but with less resolution.

### Operating conditions and specifications

**Energy range:**
The energy ranges from 5 to 90 keV, 30 keV being the most often used. Several detectors can be used to cover the whole range, from 5 to 20 keV and from 20 to 90 keV for example.

**Integration time:**
Typical integration time is few milliseconds.

**Energy resolution:**
Energy resolution of 20-30% on the detector would be used to eliminate the background.

**Spatial resolution:**
Angular resolution, which is the key point of the experiment, is obtained by the analysers. A few μrad resolution is reached. Spatial resolution (several hundreds of microns) in the direction perpendicular to the resolution direction of the analysers can be used in two different ways:
- to resolve the axial direction of the photons, leading to more accurate calculations of the 2θ position (this would limit the defaults due to the curvature of the rings, the centre of the detector seeing the ring later than the borders, as shown in the figure)
- to increase the solid angle acceptance, leading to more efficient detection.
Efficiency:
Due to the small acceptance of the analysers, the efficiency of the overall system has to compensate the small number of collected photons.

Dynamic range:
In order to detect the lowest achievable signals, the noise on detector has to be minimised down to ideally less than 1 count per second per element (1D detector case).

Flux on detector:
The expected flux on detector is around $10^5$ photons/s per element (1D detector case).

Particular operating conditions:
The detector is placed on an arm, limiting its size and weight (less than 10 kg for the whole system, up to 25 kg with a new diffractometre).

Required detectors
Two types of detectors, corresponding to the two strategies explained in the introduction, are required. The most important one should be a 1D or 2D counting detector with spatial resolution of 500 µm. This detector would be used after each analyser. The second one should be an assembly of detectors to cover the whole 20 arc, giving less angular resolution than the first one but recording the whole spectrum faster.

Existing detectors
ID31 is currently using 9 APD detectors behind crystal analysers for low energy applications and 9 LaCl₃ scintillators coupled to photomultipliers behind crystal analysers for high energy applications.

Short term possibilities
For the main, high resolution strategy, using analysers, a detector such as MAXiPix could fulfil the needs at low energy. For energies higher than 20 keV, the same type of detector but with GaAs or CdZnTe sensors should be envisaged.
For the second, fast strategy, without analysers, the use of a MythenII type detector [Schmitt et al., 2003] could be envisaged in the lower energy part as an element of the assembly of detectors to cover the whole $2\theta$ arc: 16 modules to cover 60 degrees at 1m from sample would give a resolution of 0.003°.

**Main required improvements**

The main expected improvement concerns the extension of the detector from 0D to 1D or 2D with same specifications and better efficiency at high energy.
### Surface diffraction

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**Aim of the detection system**

The aim of the detection system is to collect photons in order to record super-lattice reflections, reflectivity curves, crystal truncation rods (CTR) and in some cases to follow their evolution during chemical reactions or changes of experimental conditions.

**Operating conditions and specifications**

*Energy range:*

At SXRD and HE-Ph, the energy ranges from 4 to 25 keV. An extension up to 50 keV for the study of buried interfaces is envisaged on SXRD. HE-Ph carries out the majority of its experiments between 17 and 22 keV.

At DINA, the energy ranges from 2 to 40 keV, but mainly from 6 to 16 keV.

At LXRD, it ranges from 8 to 30 keV.

*Integration time:*

The objective is to reach 1 to 100 ms time resolution for the acquisition of the Bragg peak profile in order to follow the entire crystal truncation rod and its evolution (e.g. during catalysis experiments). Some experiments, with very low count rates, may require integration times up to 1 s. With the point detector, it is already possible to expose 0.1-0.2 s, but it is then necessary to scan over 20-30 points to record the Bragg peak profile. The reduction of the readout time is not critical since motors (sample and/or detector) are moved between two points. It will become more important for the following of chemical reactions. If the speed (exposure + readout times) is convenient, it should be envisaged continuous scans of the sample (movement of the 3 rotation motors will be synchronised with data acquisition). At ID32, current electrochemical reactions are stopped by stabilising the voltage during measurement. Continuous scans may be envisaged if the readout time is not longer than the exposure time.

*Energy resolution:*

Energy resolution is needed to suppress fluorescence background as well as high harmonics that are not fully eliminated by the upstream optics. Indeed, by definition, harmonics have...
energies that are multiple of the chosen energy. Thus, reflections from super-structures may appear at the same angle as reflections from the unit cell (e.g.: for $3E_0$, that is $\lambda_0/3$, $d_{3h3k3l}$ planes diffract at the same angle than $d_{hkl}$ planes), leading to misinterpretations of the diagrams. Moreover, the higher harmonics penetrates more into the sample, which generates noise on the signal.

For fluorescence suppression, a resolution of 1 keV at 10 keV is needed. Current Cyberstar point detectors (X1000 or X2000) allow an energy discrimination of about 20%, that is 2 keV at 10 keV.

Spatial resolution:
A 2D detector is needed in order to record the whole CTR in one shot and to directly integrate the signal in the direction perpendicular to the CTR profile. Electrochemical reactions, for instance, are currently carried out in stroboscopic mode: during a cycle, all the measurements are made at a given point of the CTR, then, the reaction is “reinitialised” and another point is measured.

To record the whole CTR in one shot, a size of $3 \times 3 \text{ cm}^2$ is the minimum required. In the case of GISAXS, an extension in at least one direction (e.g. $3 \times 7 \text{ cm}^2$) would be necessary. $10 \times 10 \text{ cm}^2$ (or even $15 \times 15 \text{ cm}^2$) would be interesting for GISAXS where the smaller the observed particles and the wider the diffracted angle. A pixel size of $50 \mu\text{m}$ is sufficient. With this pixel size, it is necessary to place the detector at around one meter from the sample. Smaller pixels could be interesting since they would permit to place the detector closer. If the detector is placed at the same distance, smaller pixels will receive less flux (smaller solid angle per pixel) and thus be less sensitive to count rate limitations.

Point detector may still be used in the case where the use of a crystal analyser is needed (background elimination or measurement of the diffracted beam polarization).

Efficiency:
Currently, it is not the limiting parameter but it should be improved for the highest part of the energy range, in particular for the study of buried interfaces.

Dynamic range:
The intensity ratio between the maximum of a Bragg peak and the minimum of the crystal truncation rod (where the changes linked to the surface state appear) is around $10^6$ to $10^8$. This implies either a dynamic range of 20 to 26 bits, either the use of filters to measure the maxima, such as it is the case now (at ID32, the point detector is linear up to 50 000 counts per second, and filters with transmission from 0.2 to $0.2^{15}=3 \times 10^{-11}$ are used for higher fluxes). It is important to be able to measure the highest peaks but with less precision than the weak ones, that are the interesting ones for the surface analysis. As now, the filters should be put automatically, as a function of the measurement at previous point.

On the beamlines, current point detectors can count up to 100 000 counts per second with good linearity and even up to 400 000 counts per second, but they can be saturated before, depending on the time structure of the beam (in the 4-bunch or 16-bunch mode, the intensity per unit of time is larger than in uniform mode).

For a given pixel, the intensity will change slowly, with the possible apparition or extinction of Bragg peaks of a superstructure during the reaction.

Linearity:
At DINA, linearity over 8 decades is desired. Otherwise, same linearity as what is obtained with current detector up to 50 000 counts per second is sufficient.
Flux on detector:
The flux reaching the sample is $10^{13}$ photons/s. Most intense Bragg peaks have an intensity of around 10% of the incident beam, that is $10^{12}$ photons/s reaching the detector in the peak. If it is possible to “disconnect” the pixels seeing uninteresting peak, it could permit to use efficiently the other parts of the detector (supposing that radiation damage will not affect definitively those pixels).
The least intense signals can be as small as a few counts per second. In that case, at ID32, the background is eliminated by the use of a crystal analyser placed in Bragg conditions in front of the detector. This will not be possible with a 2D detector.

Particular operating conditions:
Since very intense peaks (for example, during the alignment) can reach the detector, radiation damage is an important issue. In the case of the intense diffraction peaks used for sample alignment, filters can easily be used. With a 2D detector, a region of interest will be defined around the Bragg peak to be studied. During the truncation rod scan, other areas of the detector might be illuminated by strong peaks appearing for particular angles. These high intensities may damage the detector, without the possibility of adding filters. Particular care to radiation hardness will have to be taken.
The detector is installed on an arm with angular excursions of 70 degrees in vertical direction and 45 degrees in horizontal direction: this implies weight and size limitations. The MaxiPix format is suitable.

DINA may use the detector in vacuum ($10^{-1}$ to $10^{-2}$ mbar).

Other comments:
2D detectors will probably replace current point ones because of the gain of time they will potentially offer (acquiring a whole scan in one shot). The gain will be significant only if dedicated software is developed so that the integration over a chosen direction can be made, either by in-line computer software, either by the detector itself. Other features such as multi ROI, instantaneous integrated intensity with background subtraction, flat field calibration-correction would be useful.

Required detector
The required detector is a 2D detector with large dynamic range.

Existing detectors
ID01 is currently using point detectors (Cyberstar, SDD Röntec and Amptek, Braun), 1D Vantec and 2D detectors (Princeon CCD with phosphors). Main drawback of CCD is the noise. ID01 has tested Pilatus successfully but needs smaller pixels. MaxiPix detector was also successfully tested.
ID03 is currently using Cyberstar point detector (with slits and scanning the peaks) and has tested successfully a MaxiPix detector.
ID32 is currently using a Cyberstar NaI(Tl) point detector (with slits and scanning the peaks) and has tested a Pilatus.
ID10B is currently using gas detector and 1D Vantec detector.

Short term possibilities
MaxiPix pixel size is convenient. With the 1x5 assembly, a large enough q-range is covered in the direction perpendicular to the surface.
The main problem of current pixel detectors is radiation hardness. Then, the dynamic range (with good linearity) should be improved.
**Main required improvements**

Point detectors are satisfactory and will continue to be used but the goal is to replace them progressively by area detectors in many applications. The main requirement is a large dynamic range.

Another important demand concerns the need of appropriate software to analyse the acquired images.

**Other types of detectors**

*DINA* requires also other 2D detector (see page 89).

*HE-Ph* requires also energy dispersive detector (see page 94). The needs for electron detection (one hutch, 50% beam-time) are not described in this report.
High energy reflectivity

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<td>Reflectivity</td>
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**Aim of the detection system**
The aim of the detection system is to record reflectivity patterns (as a function of $q$), using a polychromatic beam combined with bent Laue crystals.

**Operating conditions and specifications**

*Energy range:*
The energy will range between **80 and 120 keV**.

*Integration time:*
Since few photons are reflected in the $q$-range of interest, integration times range between **0.1 and 1 s**, except for few experiments at lower $q$ values where milliseconds could be enough.

*Energy resolution:*
Energy resolution is not needed for this application.

*Spatial resolution:*
A 1D detector is needed to record the reflectivity diagram. 2D would be used to acquire the background at the same time as the signal. Indeed, if a 1D detector is used, it has to be moved away from the reflected beam plane in order to measure the background. Thus a 1D detector will be used only if the other specifications (mainly the efficiency) are better than what can be obtained for a 2D detector.

Spatial resolution depends on the distance between the sample and the detector. Better resolution permits to have a more compact system (smaller area and smaller distance). Placing the detector closer to the sample also reduces the contribution of air scattering.

A detector with **2k** strips or pixels of **50µm**-width would be usable at about 8 m from the sample. In the case of a 1D detector, the needed strip length is about 100 times the strip width, that is few millimetres. In the case of a 2D detector, the number of pixels in the second direction is about few hundreds.
Efficiency:
Since the experiments are carried out at high energy, efficiency of existing detectors is very low and much could be gained by improving it.

Dynamic range:
A dynamic range of 4 orders of magnitude would permit to collect the pattern in the whole interesting q-range.

Linearity:
Deviations from linearity smaller than 0.1% are desirable.

Flux on detector:
In general, the interesting q-range is far from the direct beam, and the flux is $10^6$ to $10^{10}$ less intense than the direct beam, that is only from few to few tens of thousands photons/s/stip.

Required detector
For reflectivity measurements, the required detector is at least 1D, or better 2D, detector, with high efficiency at high energy.

Existing detectors
Currently, ID15 uses a FReLoN camera with taper and CsI screen.

Main required improvements
The main expected improvement concerns the efficiency at high energy.

Other types of detectors
UPBL02 beamline requires also other 2D detectors (see pages 30 and 44) and energy dispersive detector (see page 99).
Small and wide angle scattering

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<td>SAXS and WAXS</td>
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Aim of the detection system

In SAXS and WAXS applications, the aim of the detection system is to record angular distribution of scattered photons with single photon sensitivity and high time and angular resolutions.

Operating conditions and specifications

*Energy range:*
The energy ranges from 8 to 17 keV, with the majority of experiments using a fixed energy around 12.4 keV (corresponding to a wavelength of 0.1 nm).

*Integration time:*
The purpose is to decrease the integration time down to few ms and below, and eventually down to tens of µs, in order to do stroboscopic experiments (statistics will not be satisfactory with only one 10 µs exposure for each point).
For stroboscopic experiments, shuttering may become an issue since the currently used shutters (nmLaser Products LS500) are not manufactured anymore.

*Energy resolution:*
An energy resolving capability will have an advantage in discriminating fluorescence signal.

*Spatial resolution:*
The effective angular resolution is determined by the cumulative contributions from the spatial resolution of the detector, beam size and divergence.
*For SAXS,* with the present beam parameters, the ideal spatial resolution of the detector is below 50 µm. Nevertheless, since compromises are needed, a photon counting detector with pixel size of 75 µm and high count rate and efficiency would be an attractive option for many SAXS experiments. With 75 µm, the required range of solid angle can be covered by a detector of size 120x120 mm². A larger detector is always desired in fibre diffraction type experiments. If it is not possible to obtain so small pixels, the detector size will have to be correspondingly scaled up (270x270 mm² for 170 µm pixel size) to cover the same angular range and resolution with a larger sample-to-detector distance. Nevertheless, increasing the distance implies operating in vacuum in a large volume which might not be easy.
Finally, it should be noticed that since the intensity decreases a lot when going far from the centre of the detector, it is useful to increase the active area size only if the dynamic range is...
sufficiently large to detect correctly the intensities both near the centre and near the active area borders. 

For WAXS, a spatial resolution of about 50 µm and size 60x30 mm$^2$ would be sufficient. Again dynamic range and sensitivity are similar to SAXS. Additional geometrical constraints exist when it has to be combined with SAXS: the WAXS detector should not block or even shadow the SAXS signal.

**Efficiency:**
Since samples are radiation sensitive, the detector must have good efficiency and single photon sensitivity to use the lowest possible dose on the sample and obtain good intensity statistics.

**Dynamic range:**
For the same reason, very low noise is needed. The noise should be well below the experimental background. The scattering signal decreases as the detector to sample distance is increased (a smaller solid angle is covered by each pixel). At the same time, some region of the detector may receive intense signal (e.g. diffraction peaks). In order to exploit at best a large area detector, it is necessary to have a large enough dynamic range (as explained in the “spatial resolution” paragraph). Nevertheless, the more intense is the diffracted beam and the more intense will be the scattering contributions by detector windows (or other detector parts). Thus, it appears that a hypothetical dynamic range above $10^6$ would not be efficiently used for SAXS/WAXS applications.

**Linearity:**
A linearity of 0.1% or better is desirable. At present, this level is reached after a large number of software corrections.

**Flux on detector:**
The flux depends a lot on the sample. Maximum flux on detector can reach $10^8 - 10^9$ photons/s within a few pixels in a diffraction peak or close to the primary beamstop (Gaussian tail of the incident beam, that is always present).

**Particular operating conditions:**
It is desirable to have the capability to operate in primary vacuum.

**Required detector**
2D pixel detector with small pixels and high sensitivity and dynamic range is required.

**Existing detectors**
Existing detectors at ID02 are based on CCDs. For SAXS, the detector is a FReLoN-Kodak camera, for WAXS two detectors based on large Dalsa CCDs (80 mm x 40 mm) with 1:1 coupling manufactured by Aviex LLC are under commissioning. These detectors will replace the aged Proxitronic MCP intensified CCD detectors.

**Short term possibilities**
Pilatus pixel detector (300K) is an interesting option for time-resolved experiments.

**Main required improvements**
The main expected improvement concerns the sensitivity, time resolution.
Other types of detectors

SAXS beamline requires also other 2D detectors (see page 42 and 76).
Ultra-small angle scattering

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Aim of the detection system
In USAXS, as well as in SAXS/WAXS applications, the aim of the detection system is to record angular distribution of scattered photons with single photon sensitivity and high time and angular resolutions.

Operating conditions and specifications

Energy range:
The energy ranges from 8 to 17 keV, with the majority of experiments using a fixed energy around 12.4 keV (corresponding to a wavelength of 0.1 nm).

Integration time:
Currently, USAXS is a scanning technique, but, with the beamline upgrade combined with the availability of a 2D detector with high spatial resolution and dynamic range, the purpose is to decrease the integration time down to a few ms. The USAXS technique will be then suitable for studying transient structural changes in the 100 nm to several micron range. For stroboscopic experiments, shuttering may become an issue since the currently used shutters (nmLaser Products LS500) are not manufactured anymore.

Energy resolution:
An energy resolving capability will have an advantage in discriminating fluorescence signal.

Spatial resolution:
For USAXS, a spatial resolution of about 25 µm or better is mandatory. The efficiency could be slightly compromised to reach the required spatial resolution. As explained in the section concerning SAXS, the intensity decreases a lot when going far from the centre of the detector, thus it is useful to increase the active area size only if the dynamic range is sufficiently large to detect correctly the intensities both near the centre and near the active area borders. 100x100 mm² would be a reasonable compromise.

Efficiency:
Since samples are radiation sensitive, the detector must have good efficiency and single photon sensitivity to use the lowest possible dose on the sample and obtain good intensity statistics. Nevertheless, the required angular resolution may impose the use of thin sensors, despite loss of efficiency.
Dynamic range:
For the same reason, very low noise is needed. The noise should be well below the experimental background. The scattering signal decreases as the detector to sample distance is increased (a smaller solid angle is covered by each pixel). At the same time, some region of the detector may receive intense signal (e.g. diffraction peaks). In order to exploit at best a large area detector, it is necessary to have a large enough dynamic range (as explained in the “spatial resolution” paragraph). Nevertheless, the more intense is the diffracted beam and the more intense will be the scattering contributions by detector windows (or other detector parts). Thus, it appears that a hypothetical dynamic range above $10^6$ would not be efficiently used for USAXS applications.

Linearity:
A linearity of 0.1% or better is desirable. At present, this level is reached after a large number of software corrections.

Flux on detector:
The flux depends a lot on the sample. Maximum flux on detector can reach $10^8 - 10^9$ photons/s within a few pixels in a diffraction peak or close to the primary beamstop (Gaussian tail of the incident beam, that is always present).

Particular operating conditions:
It is desirable to have the capability to operate in primary vacuum.

Required detector
2D detector with high spatial resolution and high sensitivity and dynamic range is required.

Existing detectors
This experiment will be an extension of what is has been done so far in SAXS at ID02 and no convenient detector currently exists.

Short term possibilities
The use of a 1:1 coupled FReLoN with the new EEV CCD sensor is envisaged as a first step to reach the high resolution required.

Main required improvements
The main expected improvement concerns the sensitivity, high spatial resolution and dynamic range.

Other types of detectors
SAXS beamline requires also other 2D detectors (see page 42 and 73).
Time-resolved scattering and diffraction

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<td>Time resolved SAXS, WAXS and diffraction</td>
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Aim of the detection system
The aim of the detection system is to record time-resolved diffraction and scattering patterns in order to find the structural evolution of molecules.

![Diagram of detection system](image)

Operating conditions and specifications

*Energy range:*
The energy ranges from 12 to 60 keV, with the majority of experiments around 20 keV. It is a pink beam provided by an undulator giving a thin bandwidth (ΔE/E=3%).

*Integration time:*
Currently, each image recorded by the detector is the integration of several hundreds or thousands short exposures. Typically, a 1 ps laser pulse excites the molecules. After a fixed delay (some hundreds ps), a 100 ps X-ray photon pulse interacts with the sample and the scattering is recorded by the detector. The sample is a continuous liquid flow, so that it is renewed between each excitation. This sequence is repeated until obtaining good statistics, at a rate of 1 or 3 kHz, thanks to a chopper synchronized with the laser and the synchrotron beam. Thus, each image is taken in several seconds. After the readout, the delay between the laser excitation and the X-ray exposition can be changed. The same measurement is also taken without exciting the sample by the laser in order to record the scattering of the initial state.

If the detector can be fast enough, two other schemes are planed:
- both the initial and excited states could be probed in one opening of the chopper. In 16-bunch mode, the initial state could be probed by one X-ray pulse, then, 176 ns later, the laser pulse could excite the molecules so that a second X-ray pulse could probe the excited state. In this strategy, both initial and excited states will be probed on the same sample, since in 200 ns, the continuous liquid flow will not displace much the sample. This can be obviously seen as an advantage but could also generate radiation damage artefacts.
The initial and excited states could be recorded during two consecutive apertures of the chopper that is every 1 ms. In both cases, the idea would be to record 1 image for each needed delay between excitation and probe, and then to repeat the whole sequence until reaching the desired statistics. This would imply millisecond exposure time with compatible readout time. Millisecond exposure time could also permit to follow directly chemical reactions.

Energy resolution:
Energy resolution could be used to eliminate the Compton scattering background. Nevertheless, this would imply energy resolution of few tens of eV. Indeed, according to the Klein-Nishina formula, for a 20 keV incident beam, the Compton energy shift on a 16 cm-wide detector placed at 30 cm from the sample will vary from 0 at the centre of the detector to 30 eV at 8 cm from the beam (θ=15 degrees).

Spatial resolution:
In order to collect at least 5 oscillations on the q-range, with 100 points per period, a 2D detector with 500x500 pixels is the minimum required. Nevertheless, the size of the active area should be at least 15x15 cm$^2$ in order to place the detector at around 30 cm from the sample (and to spread the diffuse background on more pixels whereas the diffracted signal will be similarly projected on the detector) and pixel size should be around 50 – 150 µm to keep an angular resolution comparable to what is currently possible. This implies at least 1kx1k pixels.

Efficiency:
In order to reduce the number of pulses necessary to obtain correct statistics, the efficiency should be optimised, in particular if an extended q-range is needed, implying the use of higher energy.

Dynamic range:
In SAXS and WAXS experiments, typical flux variations stay in a range of 10$^3$. In diffraction experiments, the integrated counts on the total active area of the detector is similar but the variation is much higher: in one 100 ps-pulse, the flux per pixel can vary from 0 count to 10 000 counts. The dark current and noise must be as stable as possible.

Linearity:
The interesting signal is the difference between the scattering signal obtained from the excited state and the one from the initial state, after normalisation of the two signals far from the centre of the detector, where the scattering corresponds to the atomic gas limit behaviour. This differential signal is about 10$^3$ times smaller than the measured one. Thus the detector must be as linear as possible on the entire dynamic range and on the whole area.

Flux on detector:
In scattering experiments, a maximum flux of 5 000 photons/s/pixel was obtained in single-bunch mode. This maximum will not be reached again in the future since single-bunch mode does not exist anymore and incident flux will be reduced (multi-layer mirror will be installed to suppress the tail of the undulator peak). In this case, counting detector could be a good solution. In diffraction experiments, the flux can go up to 10 000 photons/pulse/pixel, that is 10$^7$ photons/s/pixel in the case of a 1kHz chopper, and integrating detector should remain necessary.
Particular operating conditions:
In order to eliminate the air scattering, the sample, the beam path and the detector could be placed in vacuum or helium.

Required detector
The beamline will probably need two 2D detectors, one counting detector for SAXS and WAXS applications and one integrating detector for diffraction where the count rate per pixel can be high.

Existing detectors
ID09 is using a FReLoN Kodak with taper. Memory effects have been observed.

Main required improvements
Compared to current detector, improvements concerning the duty cycle (readout but also correction and storage times), the size, the linearity and the noise are expected.
Scattering with nano-beam

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<td>SAXS and WAXS</td>
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Aim of the detection system
The aim of the detection system is to record scattering patterns on weakly diffusing samples.

Operating conditions and specifications

Energy range:
The energy ranges from **10 to 30 keV** but the majority of experiments is carried out at 12.5 keV (1 Å wavelength).

Integration time, readout time, triggering:
Experiments carried out on the beamline concern essentially radiation sensitive samples. In that case, measurements should be as fast as possible so that the radiation damage remains negligible. Other experiments deal with stroboscopic measurements (e.g. scattering of drops). In all those situations, the exposure time, the time between two exposures and the related synchronisation between the detector, the shutter and the motors have to be optimised.
Exposure times can range from **1 to 1000 ms** but are set typically between 10 and 100 ms. The time between two measurements can vary ideally from 0 (several consecutive exposures without changing anything), few nanoseconds (motion of tens of nanometres with a piezo-motor) or a fixed arbitrary delay (several series of measurements are recorded with different delays between the triggering event and the exposure so that a kind of movie of the phenomenon can be reconstructed). Thus, the detector readout time should be as small as possible in order to cope with all these situations.

Energy resolution:
Energy resolution is useful to eliminate the signal coming from higher harmonics because the beamline is operated without deflecting mirror. It can also be used for fluorescence measurements, while rejecting the elastic peak. Energy discrimination is necessary to suppress the low energy noise of the counting detectors. **Hundreds eV** resolution would be sufficient.

Spatial resolution:
Spatial resolution is seen as a secondary priority for the beamline, in comparison with the triggering issues. The sample-to-detector distance can be adjusted between 5 cm and 2.5 m, in
order to take into account the sizes of the active area and of the pixels. A detector covering 10x10 cm$^2$ with 1kx1k pixels (or even 512x512) of 100 to 200 µm size would be satisfactory for many experiments. Another detector with 10 to 20 µm would be useful for high resolution SAXS. Nevertheless, these two sets of specifications constitute the ends of a kind of continuum of specifications and a detector with 4kx4k 50 µm pixels could fulfil the whole range of needs.

Efficiency:
Because the samples are radiation sensitive, efficiency is an important issue. Nevertheless, in many experiments, the working energy will be defined in order to maximise the detection efficiency as well as to minimise the radiation damage on the sample.

Dynamic range:
Since the samples are generally weakly diffusing, the noise has to be minimised. On the other hand, in the majority of experiments, the dynamic range is not the main issue. It is important only for certain SAXS experiments where the signal can vary on 4 to 5 orders of magnitude and for the study of Si wafers with structures, where truncation rods or satellite peaks are measured simultaneously with the Bragg peak. In this case, it is not always possible to put a beam-stop on this peak because it moves during the experiment, and also because it is used as a reference for the q position. Its intensity has not to be measured accurately but it must not saturate the detector.

Linearity:
No particular improvement is required for linearity. 0.5% deviation from linearity, over the whole dynamic range, after correction, would fulfil the requirements of the majority of experiments.

Flux on detector:
The flux is generally very low (2 000 photons/s/pixel) but it can go up to $10^8$ photons/s/mm$^2$ (that is $10^6$ photons/s/pixel for 100 µm pixels) in the case of Bragg peaks.

Particular operating conditions:
The detector should disturb the least possible the experiment (reduced vibrations, reduced heating, deported cooling system…) so that measurements at the nano-scale can be carried out.

Other comments:
The detector has to be as radiation hard as possible, or easily repaired in case of damage. The integration on the beamline (mechanics, software control, calibration procedures, flat field acquisitions…) is a very important issue.

Required detector
MiNaDif needs a 2D detector with high sensitivity and optimised speed.

Existing detectors
ID13 used a Mar CCD165, and still uses it as a reference detector, in particular for experiments requiring long acquisitions. The beamline is currently using a FReLoN 4M (Kodak sensor), a FReLoN 2k coupled with a channel plate, with a pixel size of 300 µm, but permitting the gating of the signal and a
Photonics Science camera for low-dose prealignment of highly radiation sensitive samples. A MaxiPix detector is being commissioned (first with one module, and then a 2x2 assembly).

**Short term possibilities**
The test of a Pilatus 300k is foreseen.

**Main required improvements**
The main expected improvements concern the speed, the triggering and the sensitivity. Current detectors give satisfactory results but any improvement will lead to global performance improvement of the beamline.

**Other types of detectors**
*MiNaDif* beamline require also energy dispersive detector (see page 94).
Small angle scattering on protein solutions

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<td>SAXS on proteins</td>
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Aim of the detection system
The aim of the detection system is to record SAXS patterns on proteins in solution in order to determine their 3-dimensional structures.

Operating conditions and specifications

Energy range:
The energy will range from 8 to 15 keV. ID14-3 is currently using a fixed energy of 13.3 keV.

Integration time:
The beamline will not study dynamic phenomena. The integration time will range between 1 s and tens of seconds, with readout time smaller than 1 s. In order to record both the weak wide angle signals and the strongest small angle ones, one strategy could be to accumulate frames acquired in short time, so that good statistics can also be obtained in the weak signal region. Indeed, the radiation damage mainly appear in the small angle region (which corresponds to particle shape) where few frames will be necessary whereas the wide angle region (which corresponds to atomic structure) is less sensitive to radiation damage and presents a stable signal during longer time.

Energy resolution:
Energy resolution is not needed for this application.

Spatial resolution:
Needed pixel size depends on the sample-to-detector distance, which is defined by the size of the detector (limitation on the wide angles) and by the size of the beam-stop, that contains a photodiode and cannot be smaller than 2 mm (limitation on the small angle region). The q-range needed for the protein shape resolution extends from 0.08 nm⁻¹ to 5 nm⁻¹. Taking all these elements into account, the detector should be placed at more than 2 m from the sample, and thus should measure at least 200x200 mm². Consequently, the pixel size should be around 100 µm (the spatial resolution should not be bigger than 200 µm).

Efficiency:
The efficiency already reaches around 80% and is not the limiting factor, but a single photon counting sensitivity is essential.
**Dynamic range:**
The dynamic range is not critical provided it is possible to accumulate frames. Count rate capabilities must allow the correct recording of up to 1000 photons/s/pixel.

**Linearity:**
The detector should be photon counting and linear in the whole dynamic range. It should also be very homogeneous on the whole surface.

**Flux on detector:**
The incident flux on the sample will be around $10^{12}$ photons/s/mm$^2$. The expected flux on the detector should range between 0.1 (in the wide angle region) and 1000 photons/s/pixel (near the beam-stop).

**Required detector**
*UPBL10* needs a large photon counting 2D detector.

**Existing detectors**
ID14-3 is currently using a Bruker Vantec 2000 (pixel size: 60 µm), which seems count rate limited (500 000 counts per second on the total area: 2kx2k). The useful area seems also to be reduced from 13 x 13 cm$^2$ real area to only 10x10 cm$^2$ due to parallax effects near the detector edges.

**Short term possibilities**
The possibility to use a Pilatus 1M is envisaged.

**Main required improvements**
The main expected improvement concerns the count rate and detector size which would allow to record whole required q-range in one single exposure.

**Other types of detectors**
MX beamlines require also 2D detectors for MAD experiments (see page 56) and energy dispersive detector (see page 94).
Photon correlation spectroscopy

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<td>X-ray Photon Correlation Spectroscopy</td>
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**Aim of the detection system**

The aim of the detection system is to count photons in order to record time-resolved speckle patterns in various geometries: SAXS, WAXS, GISAXS and evaluate the auto-correlation function.

**Operating conditions and specifications**

*Energy range:*  
The current energy ranges from 6 to 22 keV but 90% of the experiments are carried out between 7 and 10 keV.

*Integration time:*  
XPCS studies dynamic phenomena. The time scale ranges from nanosecond to several seconds. If XPCS can reach the microsecond domain, with a 2D detector with a frame rate better than 10 MHz, it would be unique in this field of applications. Two options appear, that can correspond to two complementary detectors:  
**Fast detector:** nanosecond time resolution on a small array (such as the APD arrays of the XNAP project) would permit to observe the fastest phenomena on a small part of the speckle pattern.  
**Large detector:** a time resolution of 10 µs or better is desired.

*Energy resolution:*  
Energy resolution is not absolutely needed. An energy resolution around 30%, as it is the case now with the used point detectors (Cyberstar OxfordDanfysik X1000) would be enough to eliminate the background.

*Spatial resolution:*  
In order to obtain large speckles and gain intensity, the coherence length is reduced by focusing the beam (currently down to ~100x20 µm²). Subsequently, the coherent part of the beam is selected by a pinhole aperture (10x10 µm²). For a given sample-to-detector distance, resolving the speckle requires a minimum spatial resolution. It seems difficult to work with pixels bigger than 100 µm.  
**Large detector:** 1kx1k pixels of 50 µm would lead to good speckle resolution at acceptable sample-to-detector distance (1-2 m). Higher speed at the expense of number of pixels is tolerable (but not less pixels than the current MaxiPix size of 256x256 pixels). The dynamic
processes can generally be repeated (equilibrium dynamics studies), so that the detector can be moved to record other region of the pattern and data can be patched together. **Fast detector:** in that case, 32x32 pixels of 100 µm would be a good starting point. This pixel size could be achieved by a mask, such as an array of holes in front of the sensor in the case of APD arrays.

The two detectors could be used at the same time, in order to increase the total recorded area, with the best achievable time resolution for each region (the speed of the speckle variation is not the same on the whole pattern).

**Efficiency:**
Efficiency is not the current limiting factor. It should be as high as possible (XPCS is limited by the signal to noise ratio). Single photon sensitivity is required.

**Dynamic range:**
The needed dynamic range highly depends on the frame rate. Indeed, when the maximum electron storage capacity of the detector is reached, the integration can be stopped and many similar frames can be accumulated to reach the desired statistics. The maximum flux on the detector and the speed are the decisive numbers.

**Linearity:**
The required detector must be single photon sensitive and linear in the whole dynamic range.

**Flux on detector:**
The coherent beam intensity reaches at maximum \(10^{10}\) photons/s in the whole beam (100x20 µm²). If one except the direct beam (that has to be blocked by a beam-stop not to damage the detector), the maximum estimated flux reaching the detector will be \(10^7\) photons/s/pixel.

**Particular operating conditions:**
The size and weight of the detector should be compatible with possible use on a 2m-diffractometer arm in vertical scattering geometry.

Because the amount of data acquired on each sample will increase a lot if the speed is increased, it will be desirable to pre-process part of the data in-line (e.g. calculating pixel averaged temporal correlation functions).

**Required detector**
**XPCS** requires a fast 2D detector with single photon sensitivity.

**Existing detectors**
Current detectors are a MaxiPix detector with one module and deep depletion CCDs in direct illumination geometry (Andor Ikon M, back illuminated, 13 µm pixel size and Princeton Instruments, front illuminated, 20 and 22.5 µm pixel size). The pixel size of the CCDs is really convenient for this application but the direct illumination scheme implies to make sure that the direct beam cannot reach the detector even during a very short time. Over-exposures or continuous exposures over many days often leads to irreversible damage of the chip (ghost images, increased dark current, dead pixels).

**Short term possibilities**
The use of larger MaxiPix (more modules) is envisaged.
Main required improvements
The main expected improvement concerns the time resolution, using a 2D detector.

Other types of detectors
*XP*CS requires also other 2D detector (see page 89).
Coherent diffraction imaging

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<tr>
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<th>Application</th>
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</tr>
<tr>
<td>UPBL01: DINA (ID01)</td>
<td>Coherent diffraction imaging</td>
</tr>
<tr>
<td>XPCS (ID10A)</td>
<td></td>
</tr>
</tbody>
</table>

**Aim of the detection system**

The aim of the detection system is to record diffraction patterns issued from coherent beam and to reconstruct images of the sample from them.

**Operating conditions and specifications**

*SMILE* envisages to carry out “ptychography” experiments, that is coherent diffraction imaging with a focused beam scanning the sample [Thibault et al., 2008]. Even if the needs are not well defined now, it is clear that ptychography will benefit from the development of 2D fast highly sensitive detectors [Chapman, 2008].

**Energy range:**

At *DINA*, the energy ranges from 2 to 40 keV, but mainly from 6 to 16 keV. At *XPCS*, the energy ranges from 6 to 22 keV but 90% of the experiments are carried out between 7 and 10 keV.

**Integration time:**

Expected integration time ranges between few milliseconds (*DINA* beamline) and 1s (*XPCS* beamline), with smaller or comparable readout times.

**Energy resolution:**

Energy resolution is not absolutely needed but discrimination capabilities would be nice to eliminate the background.

**Spatial resolution:**

Pixel size depends on the sample-to-detector distance (which has to remain compatible with the use on a diffractometre arm) and by the size of the object and the desired resolution. **1k×1k** pixels of **20 µm** would permit the oversampling necessary to get satisfactory final resolution. In that sense, detectors with even more pixels would be appreciated.
Efficiency:
Due to low coherent beam flux, efficiency has to be maximised.

Dynamic range:
Similarly to photon correlation spectroscopy, the needed dynamic range highly depends on the frame rate. Indeed, when the maximum electron storage capacity of the detector is reached, the integration can be stopped and many similar frames can be accumulated to reach the desired statistics. Nevertheless, the speed is less important for coherent diffraction imaging than for photon correlation spectroscopy: with \(10^7\) photons/s/pixel and 100 Hz frame-rate, it will be necessary to store \(10^5\) photons/pixel.

Linearity:
The required detector must be single photon sensitive and linear in the whole dynamic range.

Flux on detector:
The maximum estimated flux reaching the detector will be \(10^7\) photons/s/pixel.

Particular operating conditions:
The size and weight of the detector should be compatible with possible use on a 2m-diffractometer arm in vertical scattering geometry.

Required detector
Coherent diffraction imaging needs a 2D photon counting detector with many small pixels and high dynamic range.

Existing detectors
XPCS beamline uses CCD camera in direct illumination geometry.

Short term possibilities
The use of a FReLoN camera is envisaged at DINA beamline.

Main required improvements
The main expected improvement concerns the number of pixels and the pixel size.

Other types of detectors
DINA requires also another 2D detector (see page 67).
XPCS requires also another 2D detector (see page 86).
SMILE requires also energy dispersive detectors (see page 94).
Surface topography

<table>
<thead>
<tr>
<th>Project (Former BL)</th>
<th>Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>OPTICX (BM05)</td>
<td>Surface topography</td>
</tr>
</tbody>
</table>

**Aim of the detection system**
The aim of the detection system is to collect photons on a 2D image in order to record reflectivity, diffusion, speckle patterns on optical devices for the beamlines.

**Operating conditions and specifications**

*Energy range:*
The energy ranges from **10 to 25 keV**.

*Integration time:*
Since the flux is low, accumulation of several images is needed. The individual integration time is of the order of **10 ms**.

*Energy resolution:*
Energy resolution is not needed.

*Spatial resolution*
Spatial resolution of better than **50 µm** is required.

*Efficiency:*
Since the flux on bending magnet beamlines is low, the efficiency has to be maximised.

*Dynamic range:*
In order to accumulate a large number of images the noise has to be minimised.

*Flux on detector:*
The expected flux is at maximum **10⁹ photons/s**.

**Required detector**
The needed detector is a 2D fast, sensitive detector with very low noise in order to accumulate as many images as necessary to reach correct statistics.

**Existing detectors**
BM05 is using FReLoN camera.
Short term possibilities
MaxiPix 5x1 has been tested and should be the “ideal” detector if it was 5x5 instead of 5x1.

Main required improvements
The main expected improvements concern the speed and the sensitivity.
## Chapter 3: Energy Dispersive Detectors

<table>
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<th>Project (Former BL)</th>
<th>Application</th>
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<td>Absorption spectroscopy in fluorescence mode, spectrometry and imaging</td>
<td>94</td>
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<td>UPBL04: NINA <em>(ID22)</em></td>
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<td></td>
</tr>
<tr>
<td></td>
<td>UPBL11: TEXAS/EDXAS <em>(ID24)</em></td>
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<tr>
<td></td>
<td>PMF <em>(ID06)</em></td>
<td>Absorption spectroscopy in fluorescence mode</td>
<td></td>
</tr>
<tr>
<td></td>
<td>UPBL11: TEXAS/EXAFS <em>(BM29)</em></td>
<td></td>
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<td>XANES in fluorescence mode and spectrometry</td>
<td></td>
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<td></td>
<td>MX beamlines</td>
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<tr>
<td></td>
<td>Circular Polarization Beamline <em>(ID12)</em></td>
<td>Polarization dependant spectroscopies in fluorescence mode</td>
<td></td>
</tr>
<tr>
<td></td>
<td>MiNaDif <em>(ID13)</em></td>
<td>Spectrometry and imaging</td>
<td></td>
</tr>
<tr>
<td></td>
<td>HE-Ph <em>(ID32)</em></td>
<td>SEXAFS</td>
<td></td>
</tr>
<tr>
<td>Energy dispersive detectors for high energies</td>
<td>UPBL02 <em>(ID15)</em></td>
<td>Compton scattering and fluorescence spectrometry</td>
<td>99</td>
</tr>
<tr>
<td></td>
<td>ID15WB <em>(ID15)</em></td>
<td>Energy dispersive diffraction</td>
<td></td>
</tr>
</tbody>
</table>
# Energy dispersive detectors for low and medium energies

<table>
<thead>
<tr>
<th>Project (Former BL)</th>
<th>Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>SMILE (ID21)</td>
<td>Absorption spectroscopy in fluorescence mode, spectrometry and imaging</td>
</tr>
<tr>
<td>UPBL04: NINA (ID22)</td>
<td></td>
</tr>
<tr>
<td>UPBL11: TEXAS/EDXAS (ID24)</td>
<td></td>
</tr>
<tr>
<td>PMF (ID06)</td>
<td></td>
</tr>
<tr>
<td>UPBL11: TEXAS/EXAFS (BM29)</td>
<td>Absorption spectroscopy in fluorescence mode</td>
</tr>
<tr>
<td>UPBL07 (ID08)</td>
<td></td>
</tr>
<tr>
<td>MX beamlines</td>
<td>XANES in fluorescence mode and spectrometry</td>
</tr>
<tr>
<td>Circular Polarization Beamline (ID12)</td>
<td>Polarization dependant spectroscopies in fluorescence mode</td>
</tr>
<tr>
<td>MiNaDif (ID13)</td>
<td>Spectrometry and imaging</td>
</tr>
<tr>
<td>HE-Ph (ID32)</td>
<td>SEXAFS</td>
</tr>
</tbody>
</table>

## Aim of the detection system

The aim of the detection system is to collect photons and to analyse their energies to obtain fluorescence spectra. Spectra are then used either for fluorescence analysis (**TEXAS/EDXAS, MiNaDif, MX beamlines, NINA and SMILE**) or fluorescence yield X-ray absorption spectroscopy (**HE-Ph, MX beamlines, NINA and SMILE**) in particular in the case of very dilute or complex samples (**Circular Polarization Beamline, TEXAS/EDXAS, TEXAS/EXAFS, PMF** and **UPBL07**).

**HE-Ph, MiNaDif** and **MX beamlines** are using this type of detector as a complementary tool to their main set-up.

## Operating conditions and specifications

### Energy range:

The energy ranges from **0.2 to 30-40 keV** for all the beamlines:

- in the whole range for **MiNaDif, NINA** and **TEXAS/EDXAS**
- below 2 keV for **UPBL07**
- below 10 keV for **SMILE**
- between 1.5 and 20 keV for **Circular Polarization Beamline**
- between 5 and 25 keV for \(\text{HE-Ph}\) and the MX beamlines
- above 4 keV for \(\text{TExAS/EXAFS}\) and \(\text{PMF}\).

**Integration time:**
Currently, integration times range from **100 ms to a few seconds**. In order to reduce radiation damage on sensitive samples and to perform time-resolved or fluorescence tomography experiments, integration times should be shortened to reach, in the best case, **1 ms and at least few tens of ms**.

\(\text{PMF}\) has to reach **ms integration times** but is only interested in the integrated **intensity in a selected energy range** of the fluorescence spectrum. This integrated intensity will be stored for each point of the absorption scan in a multi-channel scaler. At the end of the scan, the entire absorption spectrum (made of the fluorescence integrated intensity collected at each point) will be transferred to the computer and saved.

**Energy resolution:**
All the beamlines require an energy resolution of **100 – 200 eV**. Better resolution could be interesting but data post-processing can separate peaks even if better experimental resolution is not reached.

On \(\text{TExAS (EDXAS and EXAFS)}\) and \(\text{SMILE}\), another detector with a **few eV resolution** could be advantageously used for spectroscopy.

**Spatial resolution:**
There is no clearly identified need for spatial resolution. Nevertheless, it could be useful to speed up some experiments such as confocal microscopy or to improve the global spatial resolution of fluorescence mapping.

**Global efficiency of the system:**
For \(\text{NINA}\), compared to present situation, the efficiency of the overall system (efficiency of the crystal, solid angle coverage, input count rate) has to be increased to compensate the loss of photons due to smaller beam size. Indeed, even if the photon flux at the beginning of the beamline will increase (machine current and upgraded insertion devices), the flux on the sample is expected to decrease due to the presence of slits and focusing devices.

For \(\text{SMILE}\), the use of a KB mirrors set-up and the machine improvements may lead to an increase of a factor 30 in flux. Thus, the main effort has to be put on an increased count rate.

For \(\text{PMF}\), since the sample is in a 30 T magnetic field, the detector cannot be placed at less than 30 cm from the sample, leading to a loss of solid angle coverage (for a given size of active area).

**Flux on detector:**
On \(\text{UPBL07, TExAS/EDXAS}\) and \(\text{NINA}\), \(10^7\) to \(10^8\) photons/s are expected on the whole detector. \(10^2\) to \(10^3\) times less are expected on \(\text{SMILE, TExAS/EXAFS}\) and \(\text{PMF}\).

Simulations based on Monte Carlo calculations [Vincze et al., 1995] are carried out in order to estimate the fluorescence and scattering fluxes as a function of the sample, the incident energy and the detection solid angle, and thus to optimise the detection strategy.

**Particular operating conditions:**
At \(\text{SMILE}\) beamline, the detector will be operated in high vacuum. At \(\text{PMF}\) beamline, the detector will be operated near high magnetic fields (30 T) that may generate stray fields up to 0.1 T. At \(\text{UPBL07}\) and \(\text{Circular Polarization Beamline}\), the detector will be operated in ultra-high vacuum and near high magnetic fields.
For the MX beamlines, the detector should be as compact as possible in order to fit in the constrained environment of MX experiments. The nose of the detector will be exposed to the nitrogen cryocooler stream used to froze the sample. 

*HE-Ph* uses such a detector for only one or two experiments per year.

### Required detectors

#### Energy dispersive detectors:

In order to maximise the overall efficiency of the detection system, the classical strategy is to increase the solid angle cone of detection. The optimal position to collect fluorescence is in the horizontal plane at 90 degrees from the incident beam direction. Going away from this position results in the collection of scattered photons and may saturate the detector with useless counts. To avoid this problem, the strategy of *NINA* and *SMILE* would be to use several high count rate, fast readout, small detectors and to place them at several positions around the sample. The high count rate and speed would give the possibility to collect a maximised useful flux, even if many photons are scattered ones. The small size would permit to place several detectors as close as possible to the sample, respecting the constraints of the experimental set-up. In that strategy, for a given size of active area, the ideal design would be the smallest possible head, with deported cooling and electronics. Using several separated detectors presents several advantages compared to assembled multi-element detectors: interactions between elements are avoided, collimation is easier and more efficient and positioning in encumbered environments is also easier.

#### Wavelength dispersive detectors:

For spectroscopy on *TEXAS/EXAFS*, when the fluorescence spectrum is not needed, the goal is to collect quickly the photons in a narrow energy band. In that case, better energy resolution is needed and the use of a WDX detector, i.e. a system using a diffractive optical element for energy selection is envisaged. The principle is explained in the following scheme (from Jakub Szlachetko, Institute of Physics, Kielce (PL) / ID21):

![Wavelength dispersive x-ray micro-fluorescence](image)

### Existing detectors

Currently, ID21, ID22, ID22NI, ID24 and BM29 are using

- multi-element Si(Li) or Ge detectors (to maximise the solid angle)
- single-element Si(Li) or Ge detectors (to be as close as possible to the sample)
- SDD detectors (to maximise the count rate) such as the SII Nanotec ‘Vortex’.

ID21 is also testing a compact “home-made” WDX detector, composed of a polycapillary, a Ge (220) crystal and a gas detector (commissioning by Jakub Szlachetko, December 2008).

ID12 is using a custom built 35-element SDD array from Eurisys-Mesures (now Canberra).

ID13 is using two Vortex SDD detectors.
ID32 and MX beamlines are using Röntec SDD detectors.

Example of strategy of use and necessity of different detectors at ID21:
Here are the characteristics of the existing detectors at ID21, and their use. For each experiment, several detectors can be used, in order to reach the best quality and efficiency. It should be noticed that for ID21, that is a low energy beamline, increasing the solid angle leads to collect only few more scattered photons: the situation is more complex at higher energies.

<table>
<thead>
<tr>
<th>ID21 (2-7keV)</th>
<th>HpGe multi-element</th>
<th>Röntec SDD</th>
<th>Compact WDX</th>
<th>Si diode + Keithley</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Active surface (mm²)</strong></td>
<td>7 x 50 = 350</td>
<td>10</td>
<td>Ø50 µm acceptance</td>
<td>50</td>
</tr>
<tr>
<td><strong>Solid angle (st)</strong></td>
<td>0.25</td>
<td>0.025</td>
<td>0.1</td>
<td>0.05</td>
</tr>
<tr>
<td><strong>Sample to detector distance (mm)</strong></td>
<td>40</td>
<td>20</td>
<td>700-800</td>
<td>30</td>
</tr>
<tr>
<td><strong>Typical count rate (photons/s)</strong></td>
<td>100 – 3000 per element</td>
<td>&gt; 5000</td>
<td>Under commissioning</td>
<td>NA</td>
</tr>
<tr>
<td><strong>Photons/solid angle (photons/s/st)</strong></td>
<td>2800 - 84000</td>
<td>200000</td>
<td>Under commissioning</td>
<td>NA</td>
</tr>
<tr>
<td><strong>Advantages</strong></td>
<td>• High sensitivity</td>
<td>• High count rate (up to 100 kcps)</td>
<td>• High energy resolution</td>
<td>• Infinite count rate</td>
</tr>
<tr>
<td><strong>Drawbacks</strong></td>
<td>• Limited count rate (&lt;20 kcps)</td>
<td>• Limited peak-to-valley ratio</td>
<td>• Crystal scan needed to get a full fluorescence spectrum</td>
<td>• Not energy dispersive</td>
</tr>
<tr>
<td><strong>Types of application</strong></td>
<td>• Mapping and XANES of trace elements (ppms)</td>
<td>• Mapping and XANES of trace elements in concentrated matrix giving high fluorescence signal</td>
<td>• Close emission lines analysis</td>
<td>• XANES of reference samples (very concentrated)</td>
</tr>
</tbody>
</table>

![Table](image)
### Comments

| To be upgraded to 50 mm² Vortex SDD |

#### Short term possibilities

Given the current existing technologies, the use of one or more SDD detectors seems the most efficient strategy. Occasionally, WDX is needed to reach the finest required resolutions. Exceptional cases require germanium detectors (either to avoid the Si K escape, or for better efficiency at energies higher than 20 keV).

**UPBL07** is in contact with Vortex® in order to buy a SDD detector customised for UHV and magnetic fields environments, as already done for APS soft X-ray spectroscopy beamline. **Circular Polarization Beamline** will continue using its 35-element SDD array.

#### Main required improvements

The main expected improvements are higher count rate and easier integration to the experimental environment.

#### Other types of detectors

- **Circular Polarization Beamline** uses also point detectors (see page 21).
- **HE-Ph** beamlines require also a 2D detector (see pages 67). The needs for electron detection (one hutch, 50% beam-time) are not described in this report.
- **MiNaDif** requires also a 2D detector (see page 81).
- **NINA** requires also 2D detectors (see pages 32 and 48).
- **PMF** requires also point detectors (see page 19) and 2D detectors (see pages 44, 50 and 59).
- **SMILE** requires also a 2D detector (see page 89).
- **TEXAS/EDXAS** requires also a 1D detector (see page 27).
- **TEXAS/EXAFS** requires also point detectors (see page 19) and a 2D detector (see page 48).
- **UPBL07** requires also point detectors (see page 23) and 2D detectors (see page 52 and 54).

The needs for electron / spin detectors are not detailed in this report.
Energy dispersive detectors for high energies

<table>
<thead>
<tr>
<th>Project (Former BL)</th>
<th>Application</th>
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<td>UPBL02 (ID15)</td>
<td>Compton scattering and fluorescence spectrometry</td>
</tr>
<tr>
<td>ID15WB (ID15)</td>
<td>Energy dispersive diffraction</td>
</tr>
</tbody>
</table>

Aim of the detection system

The aim of the detection system is to collect photons and to analyse their energies to obtain either magnetic Compton scattering spectra, fluorescence spectra or energy dispersive diffraction patterns.

Operating conditions and specifications

Energy range:
The energy ranges from **50 to 500 keV**, but most of the experiments are carried out between **80 and 120 keV**.
Integration time:
In order to perform time-resolved experiments, integration times should be shortened to reach, in the best case, 1 ms and at least few tens of ms.

Energy and position resolution:
For energy dispersive diffraction, the aim is to reach a few tens of eV resolution. As these resolution are not currently reached (current resolution of Ge detectors is around 0.5 to 1%, that is 1 keV at 100 keV), and will not probably be reached in the near future (Fano limit, lack of efficiency of bolometers…), one can combine the energy resolution of the detector and its spatial resolution (coupling it to slits). Nevertheless, to have sufficient efficiency (i.e. X-ray absorption) at high energy, the detector material must be thick, leading to a deteriorated spatial resolution, e.g. due to parallax effects. For Compton scattering, similar energy resolution are needed.

Efficiency:
Efficiency at high energy is a critical point. Nevertheless, as compared to germanium, new materials such as CdZnTe have insufficient energy resolution (currently 1.5 keV at 100 keV at -20°C and under a pencil beam [Owens et al., 2002]). Indeed, the determination of peak position is worse with poorer energy resolution than with poorer efficiency: the energy error is proportional to $\sigma/\sqrt{n}$, with $\sigma$ the detector resolution and $n$ the number of photons. CdZnTe also has spectrum energy tailing due to incomplete charge collection, and may show count rate limitations (polarization effect).

Dynamic range:
A large dynamic range is needed to resolve small diffraction peaks over high inelastic background.

Flux on detector:
In the three cases (energy dispersive diffraction, Compton scattering and fluorescence measurements), the flux reaching the detector can be as high as $10^4$ photons per millisecond. The only difference between the three cases is that in diffraction the flux is concentrated in a small solid angle, whereas in Compton and fluorescence measurement, it is spread over the whole $4\pi$ solid angle. In these cases, this flux will be reached only if the detector covers almost $2\pi$, which means a large active area placed very close to the sample.

Required detectors
Several detectors will have to be used in order to cover the whole range of specifications needed for all the experiments. To increase the count rate and be able to perform faster energy dispersive diffraction and Compton scattering experiments, segmented multi-element energy dispersive detectors could be used. Wavelength dispersive detectors would also be interesting in order to reach sub-eV energy resolution even at 500 keV for evaluation of peak shape of high energy Compton scattering. The use of a cryo-cooled detector like bolometer with ~20 eV energy resolution at 50-100keV could be envisaged to speed up those experiments [Friedrich, 2006] but maximum count rates for such high energy bolometers are low (e.g. 100cps).
**Existing detectors**
Currently, ID15 is using multi-element Ge detector (for magnetic Compton scattering), single-element Ge detectors (for energy dispersive diffraction and fluorescence analysis) and wavelength dispersive spectrometer (for high resolution inelastic scattering).

**Short term possibilities**
A 36-element arc-arrangement of Ge detectors is envisaged in order to increase the count rate and to be able to perform faster experiments.

**Main required improvements**
The main expected improvements are better energy resolution and better efficiency.

**Other types of detectors**
*UPBL02* requires also 2D detectors (see pages 30, 44 and 71).
*ID09HP, ID06LVP, ID15WB* project requires also 2D detectors (see pages 30 and 44).
PART B:
SUMMARY OF THE NEEDS
In this part, the expressed needs are summarised in five tables, each one dedicated to one of the following types of detector systems:
- point detectors,
- linear detectors,
- area detectors (split in 2 tables: detectors with pixels smaller than 50 µm and detectors with pixels larger than 50 µm),
- energy dispersive detectors.

Red-hash background highlights energy range where Si efficiency becomes low, due to weak absorption (e.g. 50% absorption for 500µm thickness at 20 keV). The main requirements are emphasised with white characters on black background. The detailed description can be found at the pages indicated as hyperlinks in the tables.
### POINT DETECTORS

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<tr>
<th>Project</th>
<th>Energy (keV)</th>
<th>Integration time</th>
<th>Flux on detector</th>
<th>Dynamic range (bits)</th>
<th>Range of use and linearity</th>
<th>Energy resolution</th>
</tr>
</thead>
<tbody>
<tr>
<td>MagScat (p14)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.3 - 1.5</td>
<td>4 - 10</td>
<td>10 - 20</td>
<td>0.5-30s</td>
<td>1-10^{12}cps</td>
<td>16</td>
<td></td>
</tr>
<tr>
<td>1.5 - 4</td>
<td></td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td>4 - 10</td>
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<tr>
<td>10 - 20</td>
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<td>20 - 50</td>
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<td>50 - 100</td>
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<tr>
<td>&lt;1µs</td>
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<tr>
<td>1µs - 1ms</td>
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<td>1ms - 1s</td>
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<tr>
<td>&gt;1s</td>
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<tr>
<td>NRS (p17)</td>
<td>6 - 14</td>
<td>- 100</td>
<td>Time resolution:</td>
<td>0.01 - 10^{3}cps</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Time resolution:</td>
<td></td>
<td></td>
<td>100ps - 100ns</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Circular Polarization Beamline (p21)</td>
<td>1.5 - 20</td>
<td>few ns</td>
<td>1ms - 100s</td>
<td>10^{-15} - 10^{-6}A</td>
<td>10^{7}</td>
<td></td>
</tr>
<tr>
<td>UPBL07 (total e- and fluo yields) (p23)</td>
<td>0.4 - 2</td>
<td></td>
<td>&lt;1s</td>
<td>10^{-12} - 10^{-7}A</td>
<td>10^{7}</td>
<td></td>
</tr>
<tr>
<td>TEXAS/EXAFS (transmission) (p19)</td>
<td>4 - 40</td>
<td></td>
<td>1ms - 1s</td>
<td>10^{8} - 10^{9}cps</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PMF (transmission) (p19)</td>
<td>4 - 40</td>
<td></td>
<td>1ms</td>
<td>10^{12}cps</td>
<td>16</td>
<td></td>
</tr>
</tbody>
</table>

**Comments**

Those needs can be fulfilled either by APDs, diodes or ionization chambers, depending on the specifications.

✓ Both MagScat and NRS projects are using APDs. For MagScat, the main expected improvements concern efficiency above 8 keV and possible evolution towards 2D detectors with determination of the polarization by the detector itself. For NRS, it concerns the time resolution (speed of the electronics). The main expected evolution is the possibility of using APD arrays, described in the 2D detectors part.

✓ Circular Polarization Beamline and UPBL07 projects focus on the detection of very low signals at high frequencies, by improving the quality of the electrometers.
## LINEAR DETECTORS (1D)

<table>
<thead>
<tr>
<th>Project</th>
<th>Width (mm) * Nb strips</th>
<th>Energy (keV)</th>
<th>Strip width</th>
<th>Integration time</th>
<th>Flux on detector (cps)</th>
<th>Energy resolution</th>
</tr>
</thead>
<tbody>
<tr>
<td>INES (p61)</td>
<td>4*640</td>
<td>5 - 14</td>
<td>&lt;50</td>
<td>&gt;1s</td>
<td>10^3 - 10^4</td>
<td>400eV</td>
</tr>
<tr>
<td>XAS-XES (p61)</td>
<td>4*640</td>
<td>5 - 12</td>
<td>&lt;50</td>
<td>10ms-10s</td>
<td>10^6</td>
<td>&lt;400eV</td>
</tr>
<tr>
<td>UPBL02 (reflectivity) (p71)</td>
<td>Few mm x2k</td>
<td>80 - 120</td>
<td>&lt;50</td>
<td>0.1 – 1s</td>
<td>10 - 10^4</td>
<td></td>
</tr>
<tr>
<td>POW (low resolution, one shot) (p64)</td>
<td>x<em>8</em>1k</td>
<td>5 - 90</td>
<td>50</td>
<td>1ms</td>
<td>10^5/strip</td>
<td>20-30%</td>
</tr>
<tr>
<td>TEXAS/EDXAS (p27)</td>
<td>1*3k</td>
<td>5 - 14</td>
<td>25</td>
<td>&lt;1μs</td>
<td>10^6 - 10^10 /strip</td>
<td></td>
</tr>
<tr>
<td>Medical, MIA (large field imaging) (p36)</td>
<td>2<em>0.1</em>3k</td>
<td>30 - 150</td>
<td>100</td>
<td>100 μs</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Comments

✓ For INES and XAS-XES projects, the use of strip detectors may be considered if they present better characteristics (energy resolution, low noise) than pixel detectors (see 2D detectors section). One spatial resolution direction is necessary to resolve the energy dispersion given by the analyser. The second direction is optional and can permit the use of several analysers as well as eliminating the signal coming from the sample environment.

✓ POW project considers to use an assembly of strip detectors placed on an arc in order to record the whole diffraction spectrum in one shot.

✓ UPBL02 project considers the use of a linear detector for reflectivity as an alternative to an area detector, if the available efficiency is better than for 2D detectors of same width and spatial resolution.

✓ TEXAS/EDXAS project considers using direct detection, on a Ge strip detector for instance, in order to improve the detection efficiency compared to what can be achieved today with the FReLoN camera.

✓ For Medical and MIA projects, a linear detector could be interesting in order to optimise the speed by taking into account the rectangular shape of the beam of the medical beamline. Ge strip detector could be used.
# Area Detectors (2D)

## Pixels smaller than 50 µm

<table>
<thead>
<tr>
<th>Project</th>
<th>Field of view (mm*mm)</th>
<th>Energy (keV)</th>
<th>Pixel size</th>
<th>Integration time</th>
<th>Flux on detector per pixel (cps)</th>
<th>Dynamic range (bits)</th>
<th>Energy resolution</th>
</tr>
</thead>
<tbody>
<tr>
<td>UPBL02 (ultra-fast imaging) (p30)</td>
<td>0.5<em>0.5 - 5</em>5 [1k*1k]</td>
<td>0.5 - 5</td>
<td>20 - 100</td>
<td>&lt;100µs</td>
<td>10⁹</td>
<td>12</td>
<td></td>
</tr>
<tr>
<td>SAXS (near field scattering) (p42)</td>
<td>&gt;0.2<em>0.2 [1k</em>1k]</td>
<td>12.4</td>
<td>&lt;1</td>
<td>few ms</td>
<td>10⁸</td>
<td></td>
<td></td>
</tr>
<tr>
<td>MIA (imaging with diffraction) (p39)</td>
<td>8<em>8 [4k</em>4k]</td>
<td>15 - 50</td>
<td>1 - 3</td>
<td>0.1 - 10s</td>
<td>10² - 10³</td>
<td>14</td>
<td></td>
</tr>
<tr>
<td>UPBL07 (emission) (p52)</td>
<td>&gt;10<em>10 [&gt;2k</em>2k]</td>
<td>0.4 - 2</td>
<td>&lt;5</td>
<td>few min</td>
<td>&lt;10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>MIA, NINA (high resolution imaging) (p32)</td>
<td>0.8<em>0.8 - 40</em>15 [4k<em>4k, 8k</em>8k]</td>
<td>6 - 60</td>
<td>60 - 150</td>
<td>0.2 - 20</td>
<td>1 - 100ms</td>
<td>10⁴ - 10⁶</td>
<td>13</td>
</tr>
<tr>
<td>UPBL07 (scattering) (p54)</td>
<td>&gt;10<em>10 [&gt;2k</em>2k]</td>
<td>0.4 - 2</td>
<td>5-10</td>
<td>&lt;1s</td>
<td>0.1 - 10⁶</td>
<td></td>
<td></td>
</tr>
<tr>
<td>MiNaDif (high resolution) (p81)</td>
<td>&gt;10<em>10 [1k</em>1k]</td>
<td>10 - 30</td>
<td>10 - 20</td>
<td>1ms - 1s</td>
<td>10⁴ - 10⁶</td>
<td>10³</td>
<td></td>
</tr>
<tr>
<td>UPBL02 (reflectivity) (p71)</td>
<td>few<em>20 - few</em>100 [~200*2k]</td>
<td>80 - 120</td>
<td>10 - 50</td>
<td>0.1 - 1s</td>
<td>&lt;100</td>
<td>10⁴</td>
<td></td>
</tr>
<tr>
<td>DINA, XPCS (CDI) (p89)</td>
<td>20<em>20 [1k</em>1k]</td>
<td>6 - 16</td>
<td>20</td>
<td>few ms - 1s</td>
<td>&lt;10³</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SAXS (USAXS) (p73)</td>
<td>100<em>100 [4k</em>4k]</td>
<td>8 - 17</td>
<td>&lt;25</td>
<td>10µs - few ms</td>
<td>&lt;10⁸</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TEXAS/EDXAS (p27)</td>
<td>&gt;50<em>1 [2k</em>x]</td>
<td>5 - 14</td>
<td>25</td>
<td>&lt;1</td>
<td>10⁴ - 10¹⁰</td>
<td>13</td>
<td></td>
</tr>
<tr>
<td>Medical, MIA (large field imaging) (p36)</td>
<td>20<em>160 [1k</em>8k]</td>
<td>30 - 150</td>
<td>20 - 30</td>
<td>100 ms</td>
<td>10² - 10³</td>
<td>16</td>
<td></td>
</tr>
<tr>
<td>SAXS (WAXS) (p73)</td>
<td>60<em>30 [1k</em>1k]</td>
<td>8 - 17</td>
<td>&lt;50</td>
<td>10µs - few ms</td>
<td>&lt;10⁴</td>
<td></td>
<td></td>
</tr>
<tr>
<td>XAS-XES (p61)</td>
<td>30<em>100 [~1</em>k*2k]</td>
<td>2.4 - 27</td>
<td>&lt;50</td>
<td>few ms - few s</td>
<td>10⁹</td>
<td></td>
<td></td>
</tr>
<tr>
<td>INES (p61)</td>
<td>15<em>50 [250</em>1k]</td>
<td>5 - 14</td>
<td>&lt;50</td>
<td>&gt;1s</td>
<td>10² - 10³</td>
<td>400 eV</td>
<td></td>
</tr>
</tbody>
</table>
## Pixels larger than 50 µm

<table>
<thead>
<tr>
<th>Project</th>
<th>Field of view (mm*mm)</th>
<th>Energy (keV)</th>
<th>Pixel size</th>
<th>Integration time</th>
<th>Flux on detector per pixel (cps)</th>
<th>Dynamic range (bits)</th>
<th>Energy resolution</th>
</tr>
</thead>
<tbody>
<tr>
<td>OPTICX (p91)</td>
<td>70<em>70 [&gt;1k</em>1k]</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PMF (single crystals) (p59)</td>
<td>25<em>25 [500</em>500]</td>
<td>3.7 - 25</td>
<td>50</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DINA, HE-Ph, LXR, SXRD</td>
<td>&gt;30<em>30 [&gt;500</em>500]</td>
<td>4 - 25</td>
<td>50</td>
<td>1 - 100ms</td>
<td>10 - 10^12</td>
<td>20-30%</td>
<td></td>
</tr>
<tr>
<td>XPCS (XPCS &quot;large det&quot;)</td>
<td>50<em>50 [1k</em>1k]</td>
<td>6 - 22</td>
<td>50</td>
<td>&lt;10</td>
<td></td>
<td>10^7</td>
<td>30%</td>
</tr>
<tr>
<td>PMF (powder) (p50)</td>
<td>500<em>500 [2k</em>2k]</td>
<td>15 - 60</td>
<td>50</td>
<td></td>
<td></td>
<td>10^1 - 10^2</td>
<td>Few 100 eV</td>
</tr>
<tr>
<td>MiNaDif (p81)</td>
<td>100<em>100 [1k</em>1k]</td>
<td>10 - 30</td>
<td>100</td>
<td></td>
<td></td>
<td>10^3 - 10^6</td>
<td></td>
</tr>
<tr>
<td>PMF (powder) (p50)</td>
<td>500<em>500 [2k</em>2k]</td>
<td>15 - 30</td>
<td>100 - 300</td>
<td></td>
<td></td>
<td>10^1 - 10^6</td>
<td></td>
</tr>
<tr>
<td>XPCS (XPCS &quot;fast det&quot;) (p86)</td>
<td>10<em>10 [32</em>32]</td>
<td>6 - 22</td>
<td>100</td>
<td>10</td>
<td>&lt;10^5</td>
<td>30%</td>
<td></td>
</tr>
<tr>
<td>-------------------------------</td>
<td>----------------</td>
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<td>-----</td>
<td>-----</td>
<td>--------</td>
<td>-----</td>
<td></td>
</tr>
<tr>
<td>NRS (p17)</td>
<td>10<em>10 [32</em>32]</td>
<td>6 - 14 - 100</td>
<td>100</td>
<td>Time resolution: 100ps - 100ns</td>
<td>10^2 - 10^5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>POW (high resolution) (p64)</td>
<td>80<em>8 [&gt;100</em>10]</td>
<td>5 - 90</td>
<td>1mm</td>
<td>1ms</td>
<td>10^5</td>
<td>20-30%</td>
<td></td>
</tr>
<tr>
<td>XAS-XES (p61)</td>
<td>30<em>100 [-10</em>10]</td>
<td>5 - 12</td>
<td>5 - 10</td>
<td>10^6</td>
<td>&lt;400 eV</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Comments**

Those needs can be fulfilled either by image plates, flat panels, CCD cameras, pixel detectors or APD arrays, depending on the specifications.

✓ **SAXS, UPBL02, MIA and NINA** projects may use **indirect detection with optical coupling** to reach the pixel size required by near-field scattering, ultra-fast imaging, imaging combined with diffraction and high resolution imaging applications. Ultra-fast imaging systems have to face fast data transfer issues. High resolution imaging requirements will imply the development of more efficient optics (including the case of large field of view) and scintillators.

✓ **Medical** and **MIA** projects may use **indirect detection with fibre-optic taper** coupling for their large field imaging application. The main issue is the efficiency at high energy.

✓ **UPBL07** project needs detectors compatible with UHV and an improvement of current global efficiency (intrinsic efficiency, faster readout with same noise and solid angle coverage). **Direct detection** is probably required.

✓ **TEXAS/EXDAS** project will privilege the use of a 1D detector but could also use few lines of a 2D detector and use the other ones for the data storage during acquisition.

✓ **UPBL02** project considers the use of a 2D detector for reflectivity as an alternative of a 1D detector, in order to measure the background simultaneously with the signal. Thus, the second dimension is not precisely defined.

✓ **OPTICX, INES, XAS-XES, PMF, DINA** (for surface diffraction), **HE-Ph, LXRD, SXRD, XPCS** (for photon correlation spectroscopy with “large detector”), **IXS-PH, MX, UPBL09b, MiNaDif, SAWX** (for small and wide angle scattering), **NINA** (for diffraction), **TEXAS/EXAFS** (for diffraction), **UPBL02** (for diffraction), **HP, MatSci** and **POW** (for the “high resolution” need) projects may use **pixel detectors** with particular specifications according to their most important needs (efficiency at high energy, speed, active area size, pixel size…).

✓ **XPCS** (for coherent diffraction imaging), **DINA** (for coherent diffraction imaging) and **SAXS** (for ultra-small angle scattering) projects need pixel detector with small pixels (<50 µm).

✓ For **XPCS** (“fast” applications) and **NRS** projects, **APD arrays** will be interesting.

✓ **XAS-XES** project already uses APDs and would be interested in keeping the same technology by testing **APD arrays**, before changing to pixel detectors.
## Energy Dispersive Detectors

<table>
<thead>
<tr>
<th>Project</th>
<th>Energy (keV)</th>
<th>Integration time</th>
<th>Output Count Rate (cps)</th>
<th>Energy resolution</th>
</tr>
</thead>
<tbody>
<tr>
<td>UPBL07 (fluor) (p94)</td>
<td>0.3 - 1.9</td>
<td></td>
<td></td>
<td>10^7</td>
</tr>
<tr>
<td>SMILE (p94)</td>
<td>0.2 - 10</td>
<td></td>
<td></td>
<td>10^6</td>
</tr>
<tr>
<td>Circular Polarization Beamline (fluor) (p94)</td>
<td>1.5 - 20</td>
<td>1-100s</td>
<td>1ms</td>
<td>10^8</td>
</tr>
<tr>
<td>TEXAS/EDXAS (fluor) (p94)</td>
<td>1 - 30</td>
<td>1ms</td>
<td>10^8</td>
<td></td>
</tr>
<tr>
<td>NINA (fluor) (p94)</td>
<td>1 - 40</td>
<td>1ms</td>
<td>10^7 - 10^8</td>
<td></td>
</tr>
<tr>
<td>PMF (fluor) (p94)</td>
<td>4 - 40</td>
<td>1ms</td>
<td>10^6</td>
<td></td>
</tr>
<tr>
<td>TEXAS/EXAFS (fluor) (p94)</td>
<td>4 - 40</td>
<td>&lt;1s</td>
<td>10^7</td>
<td></td>
</tr>
<tr>
<td>MiNaDif (fluor) (p94)</td>
<td>10 - 30</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HE-Ph (fluor) (p94)</td>
<td>5 - 25</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MX (fluor) (p94)</td>
<td>5 - 25</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>UPBL02 (energy dispersive) (p99)</td>
<td>50 - 500</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SMILE (p94)</td>
<td>0.2 - 10</td>
<td></td>
<td></td>
<td>10^6</td>
</tr>
<tr>
<td>TEXAS/EXAFS (fluor) (p94)</td>
<td>4 - 40</td>
<td>&lt;1s</td>
<td>10^7</td>
<td>1-10 eV</td>
</tr>
<tr>
<td>UPBL02 (energy dispersive) (p99)</td>
<td>50 - 500</td>
<td></td>
<td></td>
<td>20 eV</td>
</tr>
</tbody>
</table>

### Comments

Those needs can be fulfilled either by solid-state Ge or Si(Li) detectors, SDD or WDX, depending on the specifications. The high resolution requirements, which cannot be addressed by solid state detectors, are regrouped below the thick blue line. The output count rate have been estimated according to the currently used geometry.
BIBLIOGRAPHY


Goulon et al. (2005), 'Advanced detection systems for X-ray fluorescence excitation spectroscopy', Journal of Synchrotron Radiation 12, 57-69.


# GLOSSARY

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>ADC</td>
<td>Analog to Digital Converter</td>
</tr>
<tr>
<td>APD</td>
<td>Avalanche Photo-Diode</td>
</tr>
<tr>
<td>CCD</td>
<td>Charge Coupled Device</td>
</tr>
<tr>
<td>CMOS</td>
<td>Complementary Metal Oxide Semiconductor</td>
</tr>
<tr>
<td>CTR</td>
<td>Crystal Truncation Rod</td>
</tr>
<tr>
<td>DQE</td>
<td>Detection Quantum Efficiency</td>
</tr>
<tr>
<td>EDX</td>
<td>Energy Dispersive X-ray detector</td>
</tr>
<tr>
<td>EXAFS</td>
<td>Extended X-ray Absorption Fine Structure</td>
</tr>
<tr>
<td>FWHM</td>
<td>Full Width at Half Maximum</td>
</tr>
<tr>
<td>FY</td>
<td>Fluorescence Yield</td>
</tr>
<tr>
<td>Gadox</td>
<td>Gadolinium Oxide</td>
</tr>
<tr>
<td>GGG</td>
<td>Gadolinium Gallium Garnet</td>
</tr>
<tr>
<td>GISAXS</td>
<td>Grazing Incidence Small Angle X-ray Scattering</td>
</tr>
<tr>
<td>HP</td>
<td>High Pressure</td>
</tr>
<tr>
<td>I</td>
<td>Intensity measured after photon-sample interaction</td>
</tr>
<tr>
<td>I₀</td>
<td>Intensity of the photon flux arriving on the sample</td>
</tr>
<tr>
<td>KB</td>
<td>Kirkpatrick-Baez (focusing mirrors)</td>
</tr>
<tr>
<td>LuAG:Ce</td>
<td>Ce doped Lu₃Al₅O₁₂</td>
</tr>
<tr>
<td>LVP</td>
<td>Large Volume Press</td>
</tr>
<tr>
<td>MAD</td>
<td>Multiple-wavelength Anomalous Diffraction</td>
</tr>
<tr>
<td>MCA</td>
<td>Multi-Channel Analyser</td>
</tr>
<tr>
<td>MCP</td>
<td>Micro Chanel Plate</td>
</tr>
<tr>
<td>NFS</td>
<td>Near Field Scattering</td>
</tr>
<tr>
<td>PSF</td>
<td>Point Spread Function</td>
</tr>
<tr>
<td>RIXS</td>
<td>Resonant Inelastic X-ray Scattering</td>
</tr>
<tr>
<td>ROI</td>
<td>Region Of Interest</td>
</tr>
<tr>
<td>SAXS</td>
<td>Small Angle X-ray Scattering</td>
</tr>
<tr>
<td>SDD</td>
<td>Silicon Drift Diode</td>
</tr>
<tr>
<td>SEXAFS</td>
<td>Surface Extended X-ray Absorption Fine Structure</td>
</tr>
<tr>
<td>SNR</td>
<td>Signal to Noise Ratio</td>
</tr>
<tr>
<td>TEY</td>
<td>Total Electron Yield</td>
</tr>
<tr>
<td>UHV</td>
<td>Ultra-High Vacuum</td>
</tr>
<tr>
<td>USAXS</td>
<td>Ultra-Small Angle X-ray Scattering</td>
</tr>
<tr>
<td>WAXS</td>
<td>Wide Angle X-ray Scattering</td>
</tr>
<tr>
<td>WDX</td>
<td>Wavelength Dispersive X-ray detector</td>
</tr>
<tr>
<td>XANES</td>
<td>X-ray Absorption Near Edge Structure</td>
</tr>
<tr>
<td>XAS</td>
<td>X-ray Absorption Spectroscopy</td>
</tr>
<tr>
<td>XMCD</td>
<td>X-ray Magnetic Circular Dichroism</td>
</tr>
<tr>
<td>XPCS</td>
<td>X-ray Photon Correlation Spectroscopy</td>
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