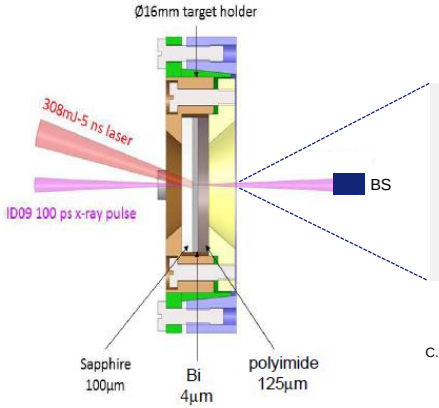
SINGLE-PULSE EXPERIMENTS FOR DYNAMIC COMPRESSION AND STRUCTURAL DYNAMICS

Michael Wulff, ID09

Complex Systems and Biomedical Sciences Group

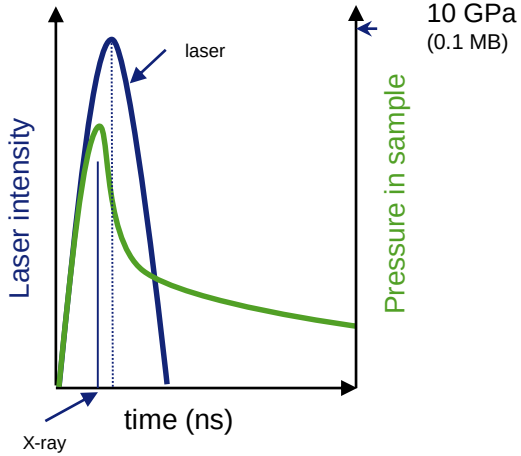


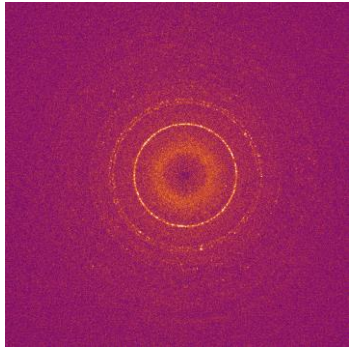
Area detector (Rayonix HS170)

Diffraction & scattering

C. M. Pepin et al., PHYSICAL REVIEW B **100**, 2019

5 ns laser pulse, 300-400 mJ @ 1064 nm

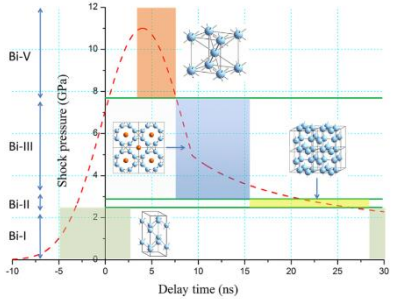




Single-pulse pattern

β-Sn

R. Briggs et al., J. Synchrotron Rad. 26, (2019).

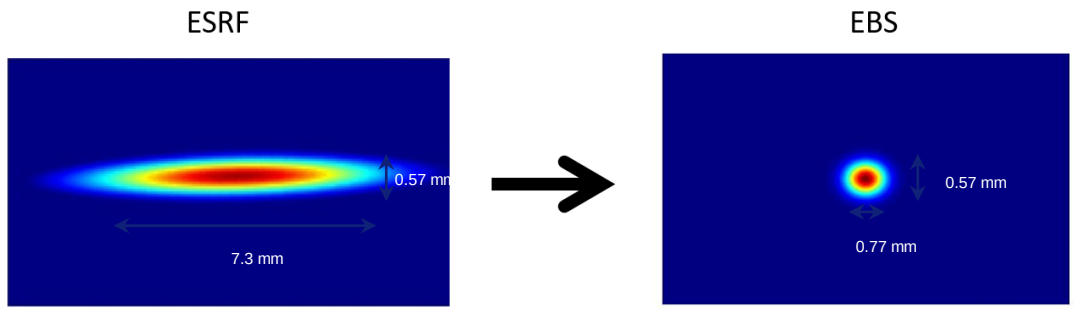


EBS News

Extremely Bright Source (EBS)

7 permanent magnets

Beam 27 m from source)



beam sizes = 3 σ values

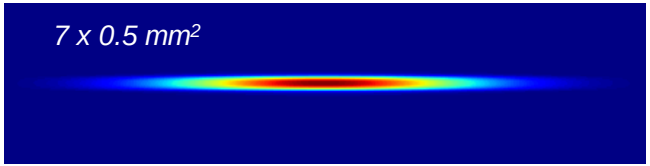
Benefits for ID09

- *3 fold gain in spectral intensity*
- *4 fold smaller focus (area)*
- *1.5 fold gain in pulse intensity*
- *Heat load reduced to 30% of ESRF level*

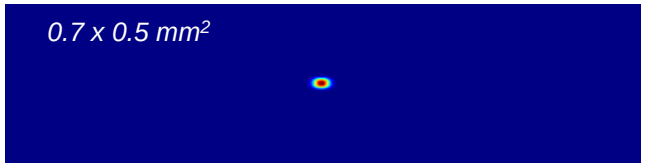
EBS BEAM (ID09)

Raw beam at 27 m (primary slits)

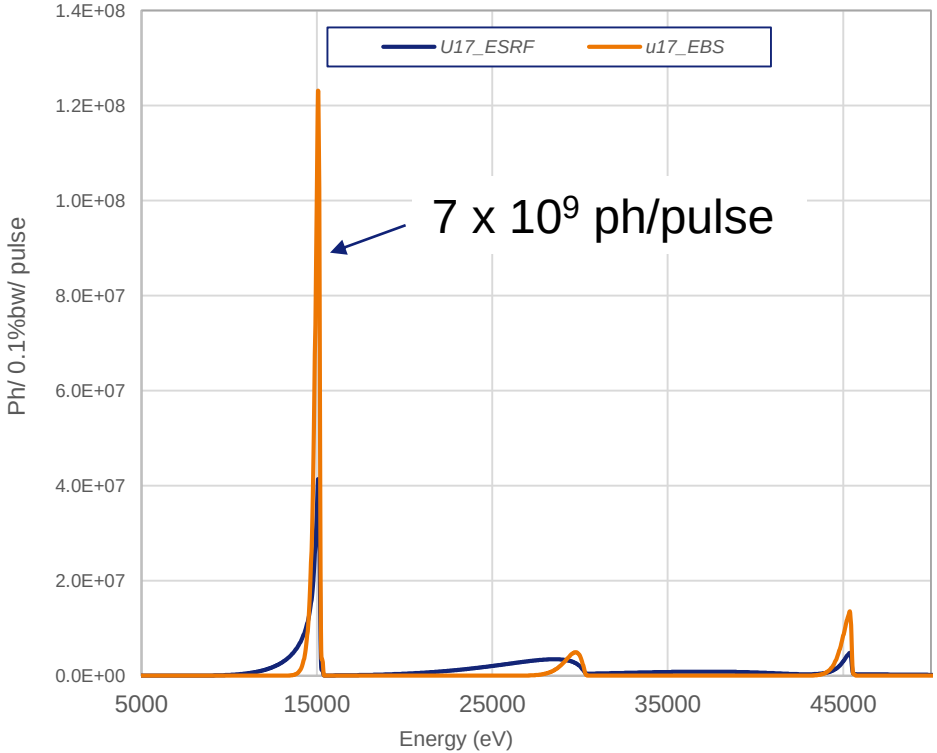
ESRF



EBS

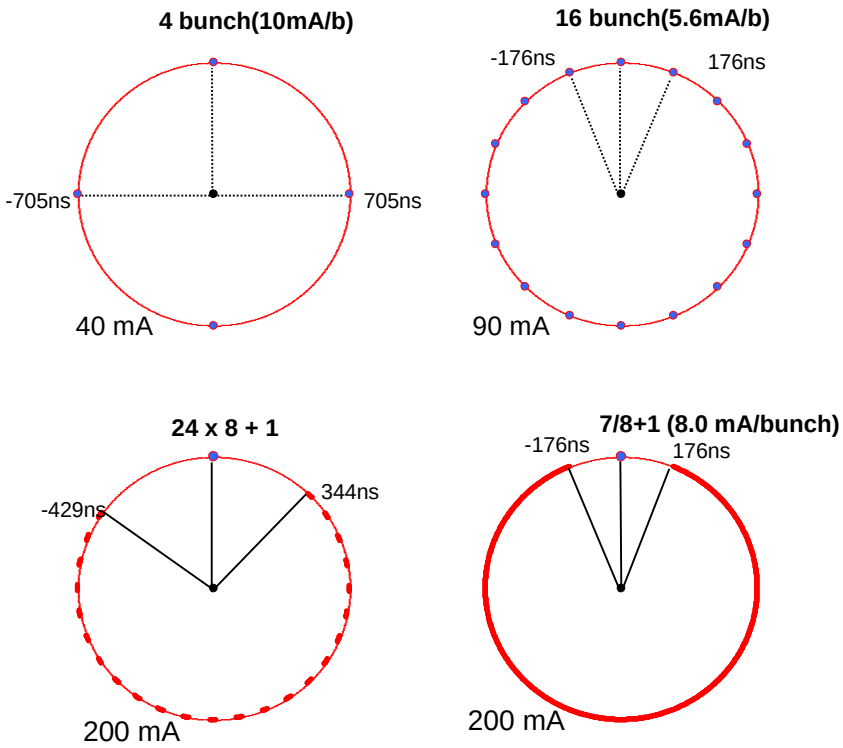


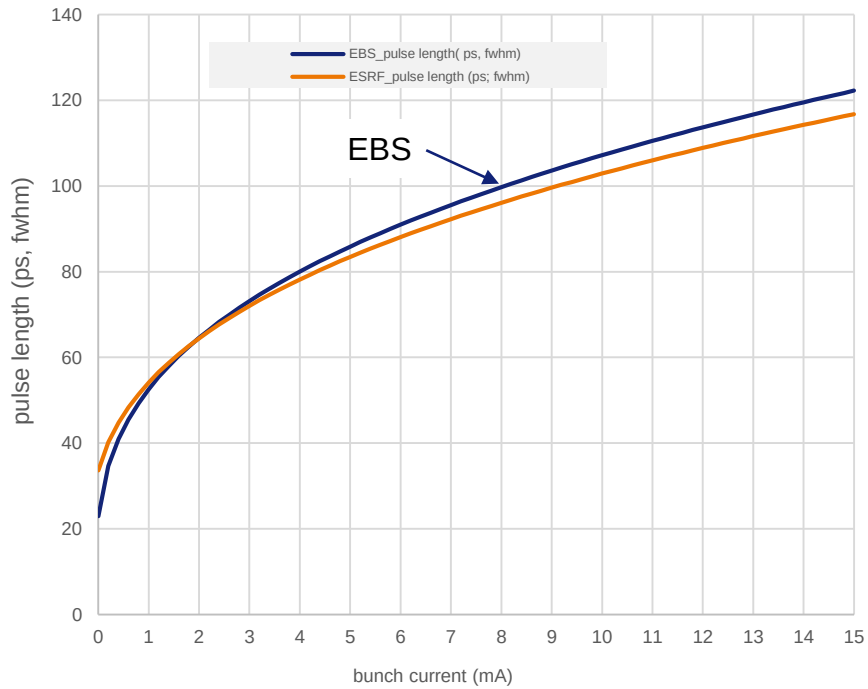
-	EBS
Pulse intensity (ph/pulse/2% BW)	7 E+09
Undulator bandwidth	2.1%
Pulse length (ps, fwhm)	100



Sharp undulator spectrum makes pink-beam diffraction possible! 10-20 fold gain in intensity

EBS BUNCH MODES AND PULSE LENGTH





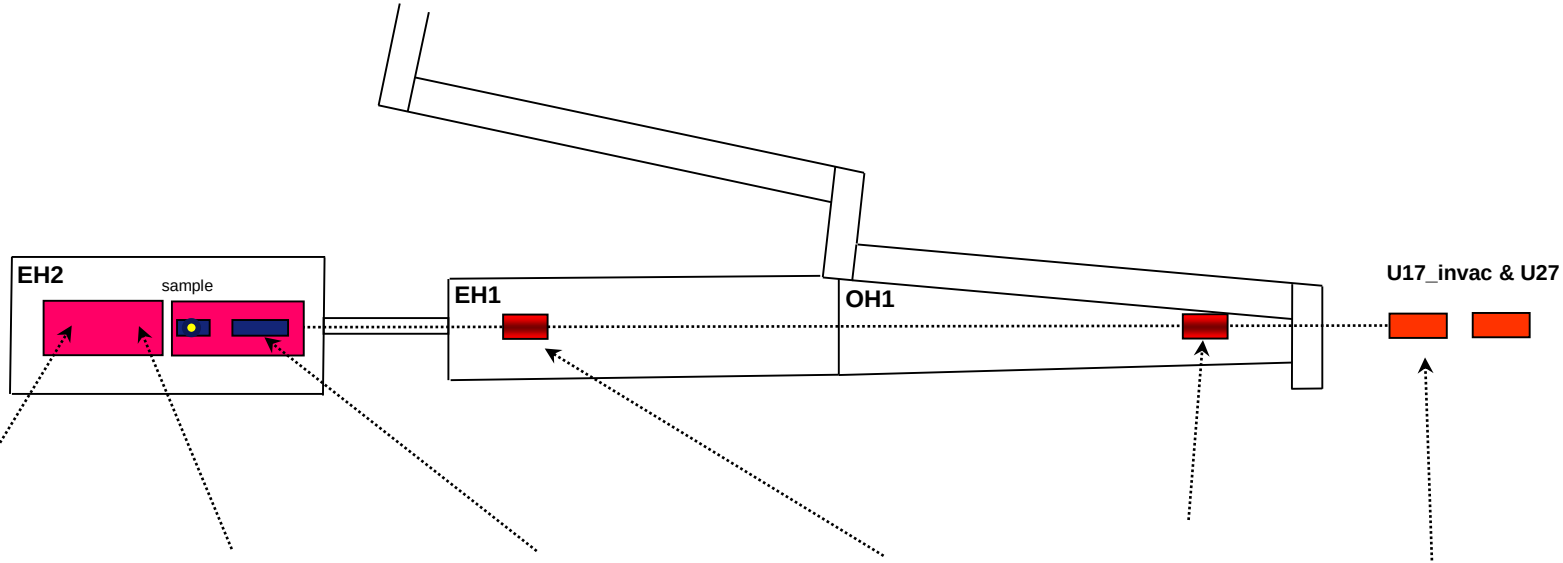
<u>Pulse length is the same as for ESRF, ~ 100 ps (fwhm)</u>

Currently the bunch current is limited to 3 mA due to degassing problem in transfer line
Should be raised to 8 mA at end of 2021.

ID09 NEWS

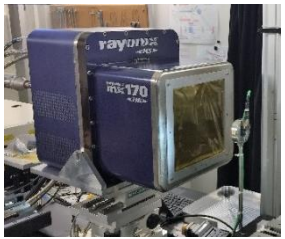
ID09 INSTRUMENTATION

Beamline for pink-beam-experiments in pump-probe (diffraction & XES)

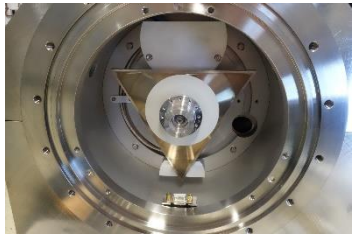


Lasers

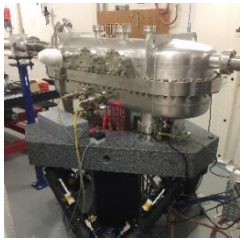
CCD detector



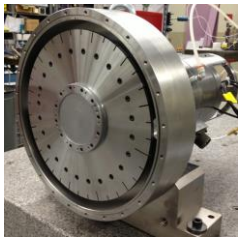
Nanosecond chopper



Focusing Mirror

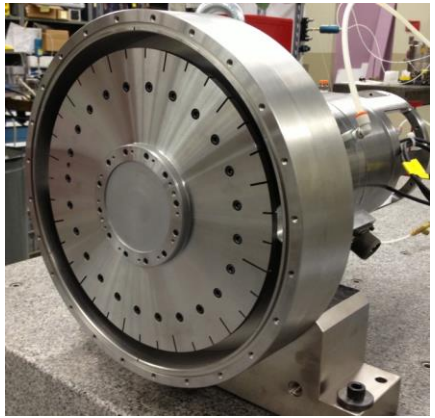


Heat load chopper

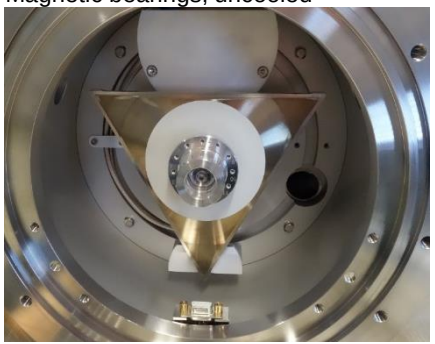


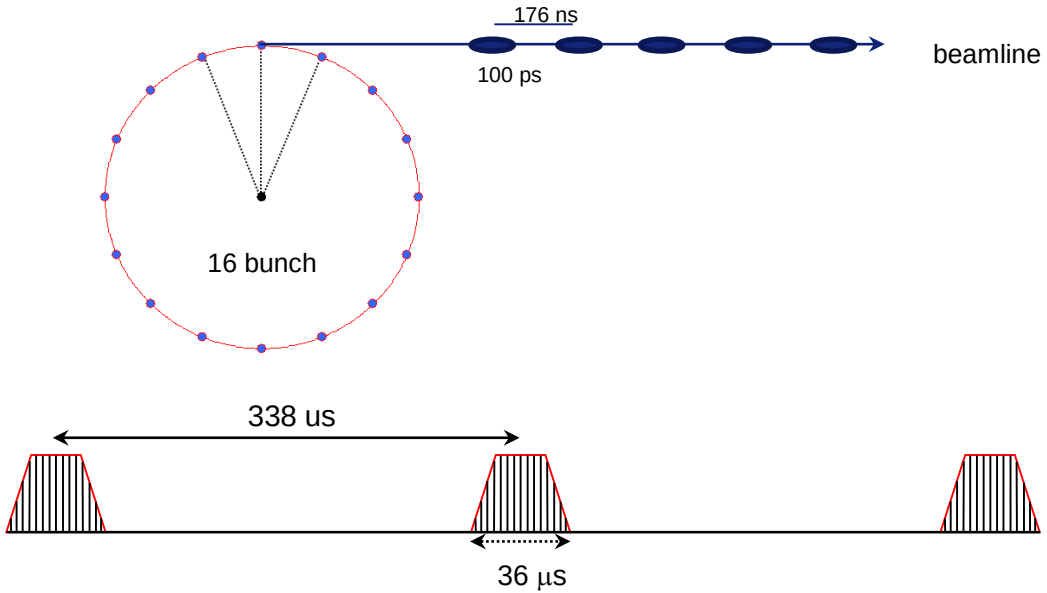
CHOPPER SYSTEM FOR ISOLATING SINGLE PULSES AT UP TO 3000 HZ

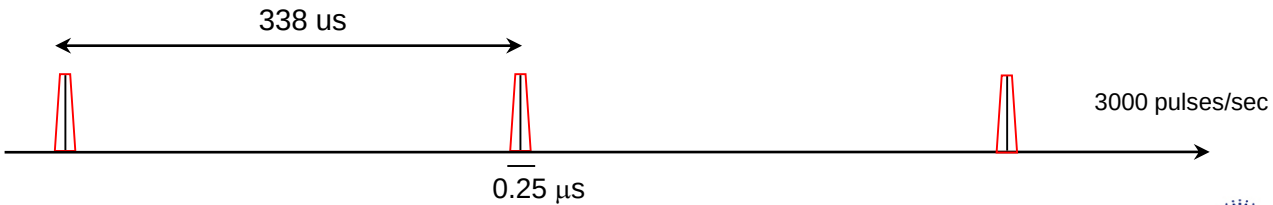
Chopper (rotates 82.2 Hz)
Airbearings, cooled. Power transmission 2.4%



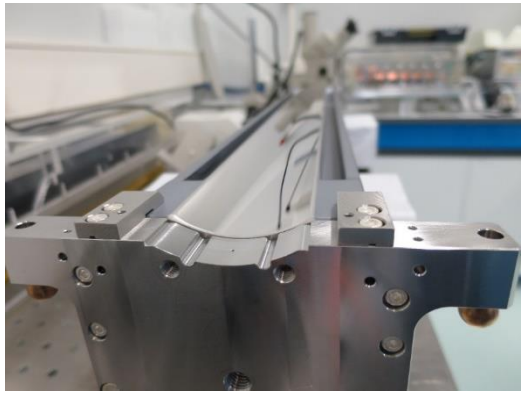
Julich nanosecond chopper (rotates 986.3 Hz)
Magnetic bearings, uncooled



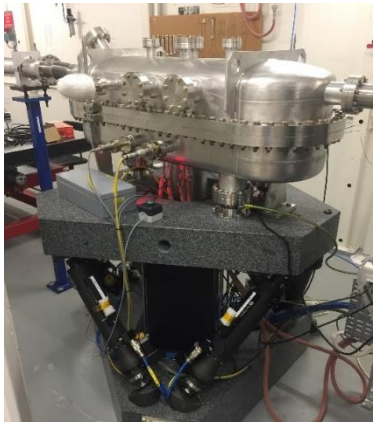


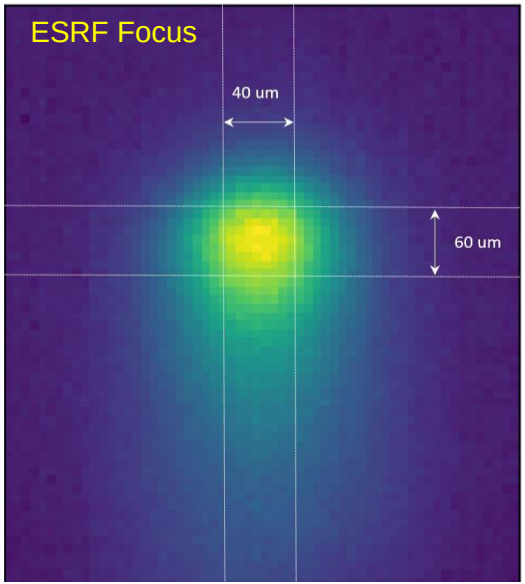


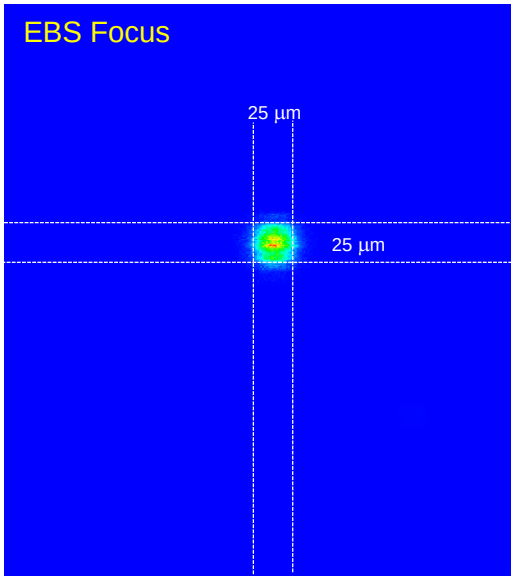
NEW TOROIDAL MIRROR



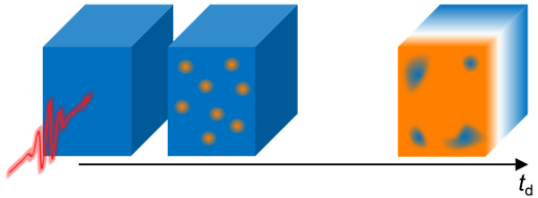
Length	600 mm
Shape	cylindrical + bender
Coating	Pd
Incidence angle	2.45 mrad
Energy-cut-off	24 keV
Demagnification M	0.27

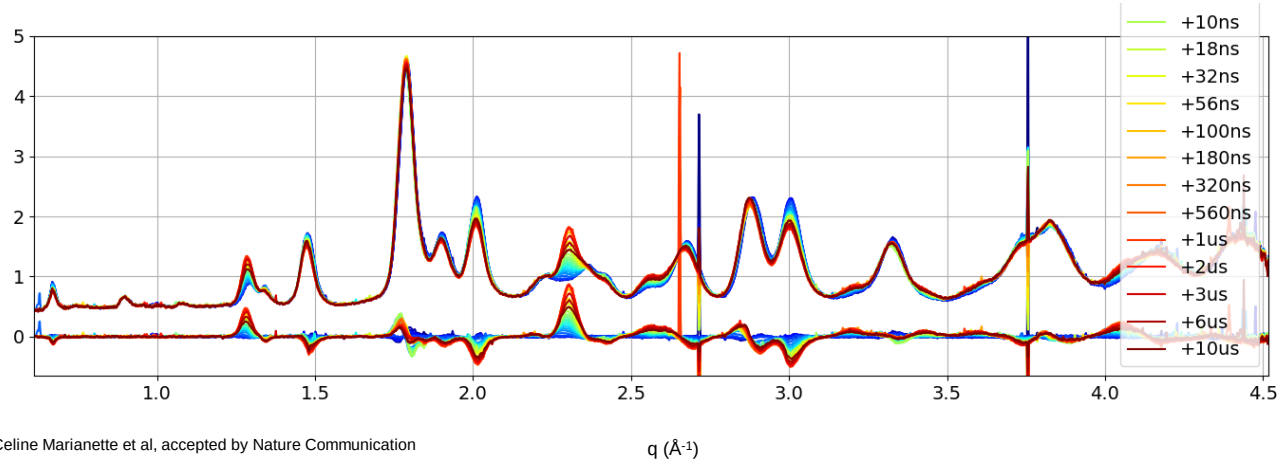




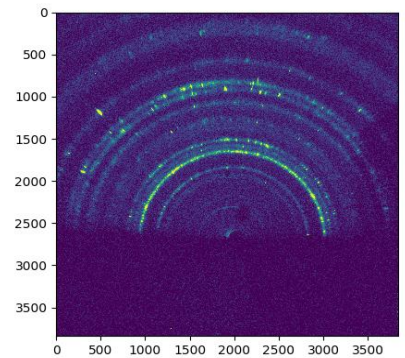


TI3O5: SEMICONDUCTOR → METAL TRANSITION IN NANOCRYSTALS





Celine Marianette et al, accepted by Nature Communication



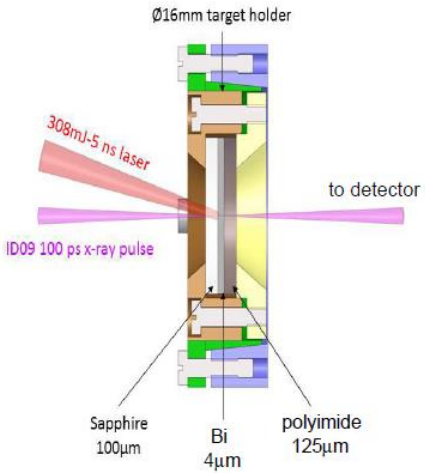
2.1 % pink beam powder diffraction @11 keV

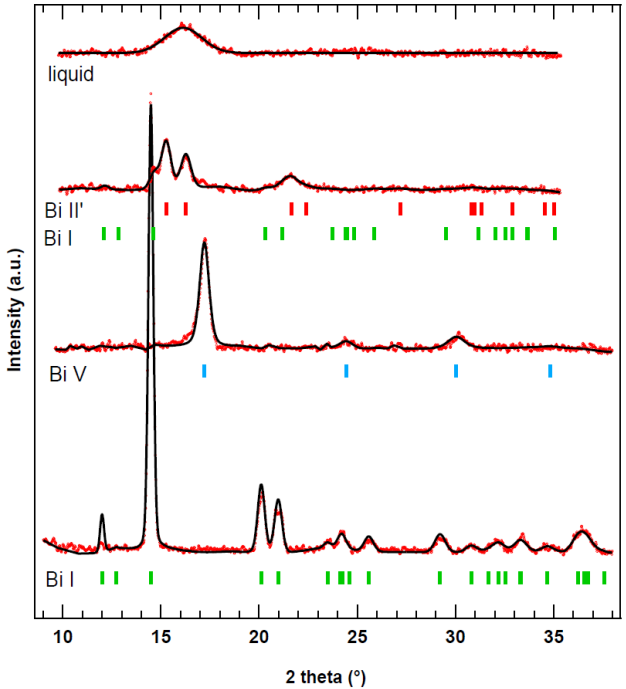
Power diffraction feasible with 2% pink beam

Experiments from ID09

DYNAMIC COMPRESSION ON BISMUTH (SINGLE PULSE DIFFRACTION)

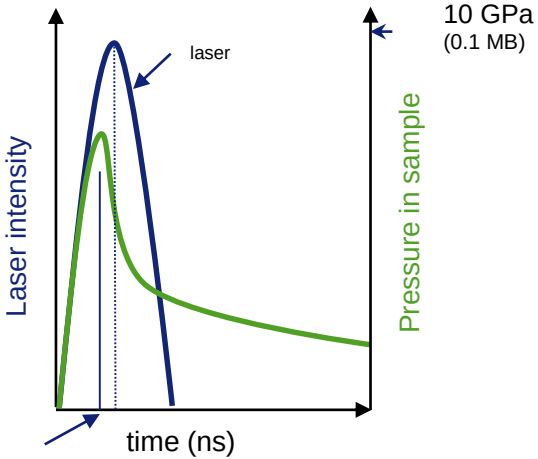
4 phases probed by varying laser/X-ray delay. Details in Charles Pepin's talk.

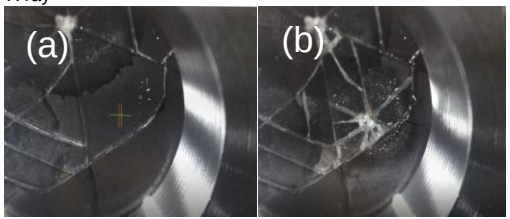




C. M. Pepin et al., PHYSICAL REVIEW B **100**, 2019

5 ns laser pulse, 300-400 mJ @ 1064 nm





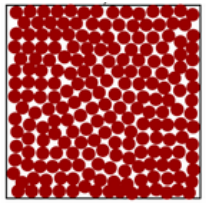
Experiment done with Ru multilayer monochromator and 4×10^8 ph/pulse @ 15 keV.

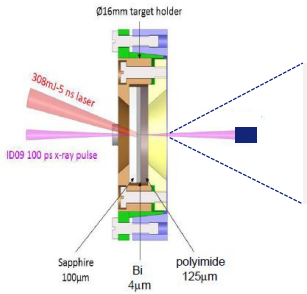
10-20 fold gain in intensity with EBS

LIQUID SODIUM IN A SINGLE-PULSE WITH 1 X 10^{10} PH / PULSE AT 15 KEV

$$Pixel\ intensity:\ I_p = I_0\, r_0^2\, N(Na) D_{DQE}\ P\, S_{Na}\, d\Omega_p$$

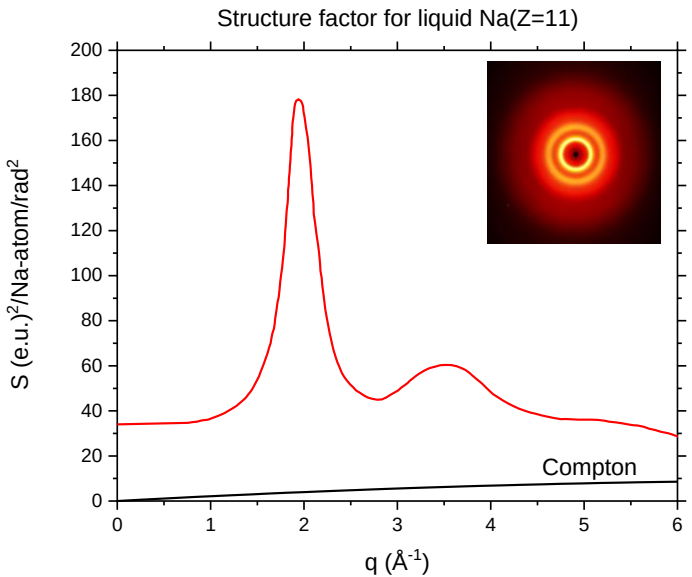
Atomic liquid of Na



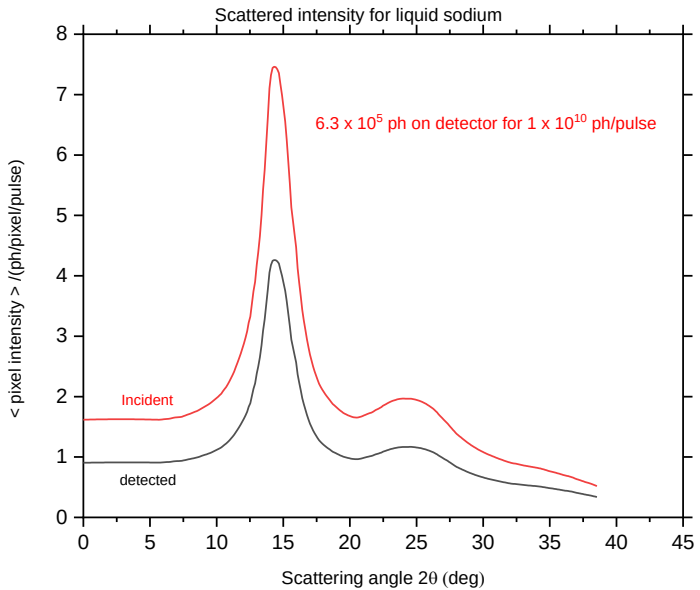


detx 40 mm
pixel 0.088 mm

I_0 :	1.60E+13 ph/mm^2/pulse
Focus:	0.025 x 0.025 mm^2
Sample t:	0.005 mm
N(Na):	7.9E+13 atoms in beam
detx:	40 mm
Pixel:	0.088 x 0.088 mm^2 (Rayonix HS170)



Na data from B. E Warren'book "X-ray Diffration" Hard Sphere Model, p 125.



SUMMARY

- Dynamic compression at up to 0.1 MB done on ID09
- Diffraction and scattering possible with pink beam (2.1% BW)
- 10-20 fold increase in pulse intensity (10^{10} ph/pulse)
- Vacuum chamber around sample mandatory
- Jungfrau pixel detector could greatly increase S/N ratio
- 3-10 J nanosecond laser is needed for ID09

ACKNOWLEDGEMENT TO PRESENT AND FORMER ID09 STAFF

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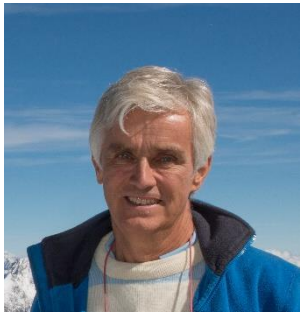
Scientist

Serhane Zerdane
postdoc



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Thank you for your attention!