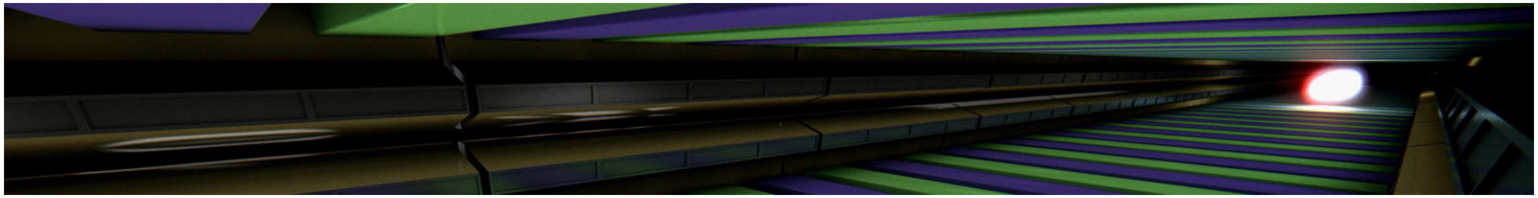

A diamond crystal bender for spectral diagnostics

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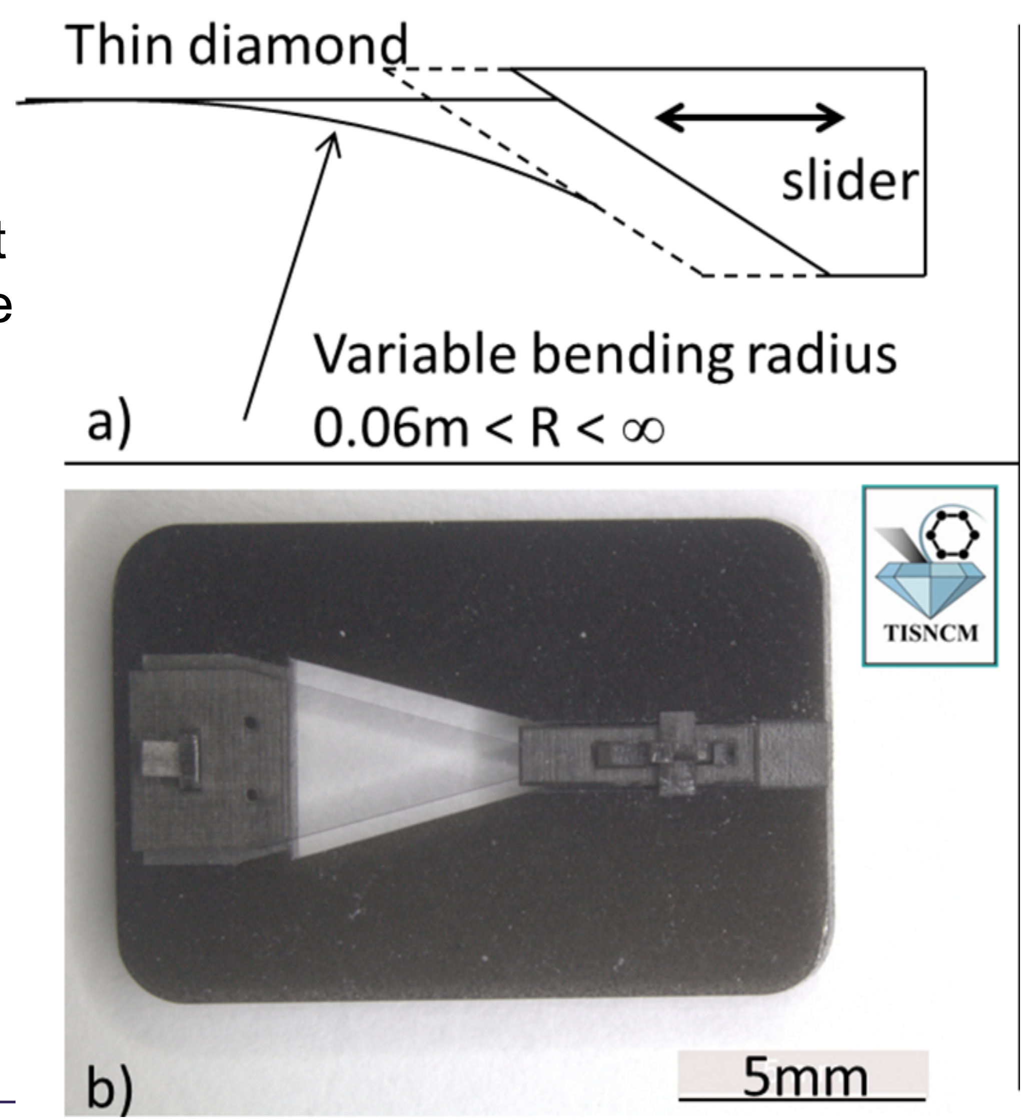
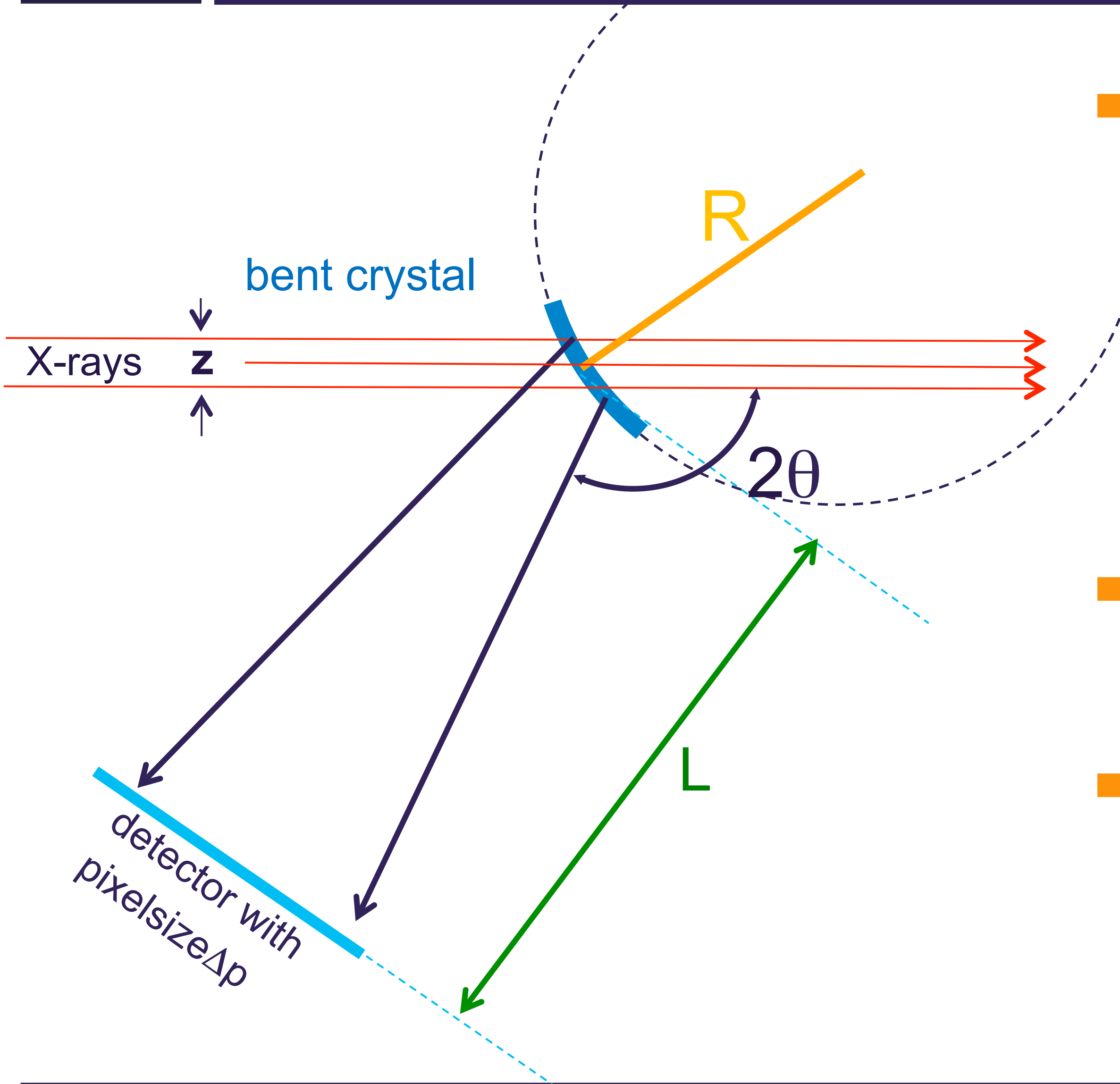
8^{th} Hard X-ray FEL Collaboration Meeting,
Pohang, Korea

Aims and Motivation

- Measurement of the energy dispersion within a single pulse with high resolution.
- Challenges at EU.XFEL with bent Si- spectrometer and 4.5MHz due to thermal load foreseen.
- Measurements on single shot basis (120 Hz @ LCLS and 4.5MHz @ EU.XFEL).
- Test of a diamond crystal-bender at LCLS with variable bending radius in February 2016.
- Simultaneous comparison of diamond and silicon analyzer crystals.



A bent-crystal spectrometer



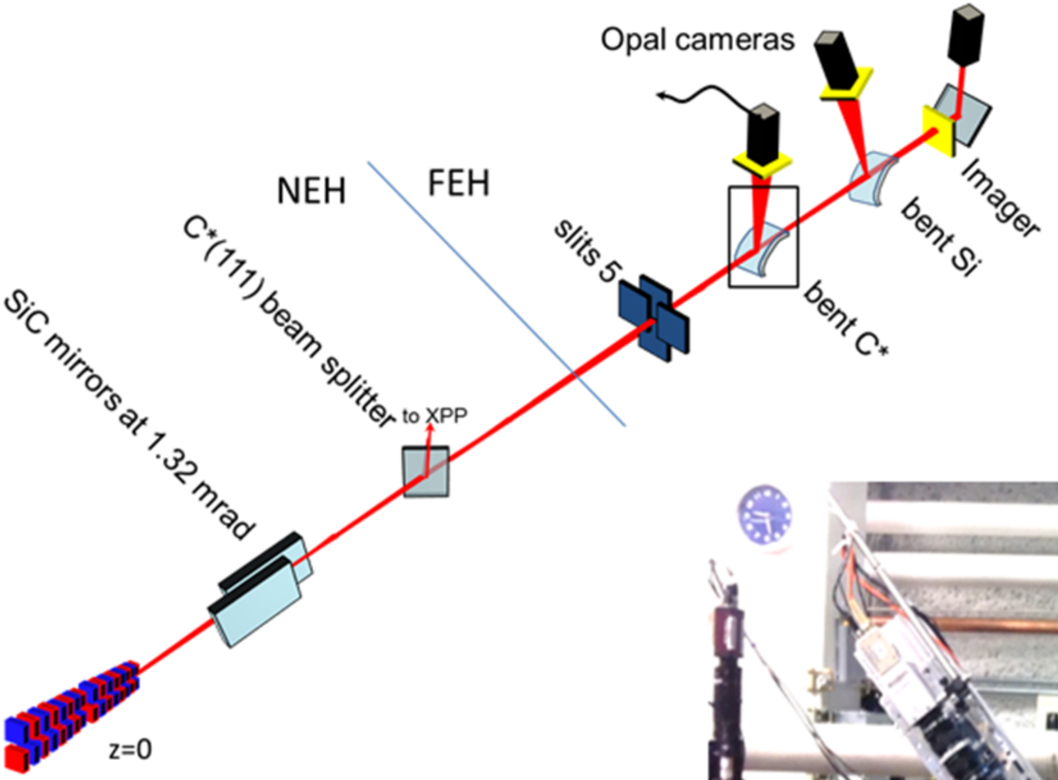
- Energy resolution: Function of detector pixel size, bending radius R, energy and detector distance L:

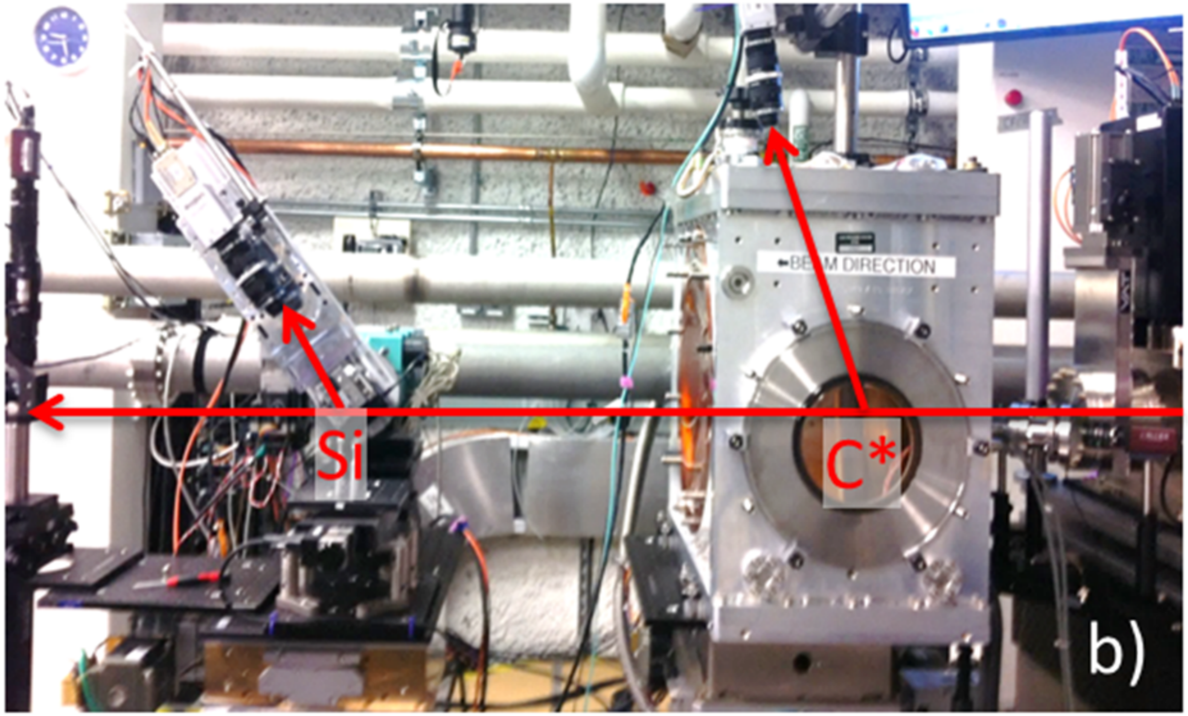
$$\frac{\Delta\lambda}{\lambda} = \frac{\Delta p}{\tan\theta \cdot (2L + R\sin\theta)}$$

- The effect of the bending radius is on the energy resolution is negligible, here.
- Energy range: Function of energy, beamsize z and bending radius R:

$$\frac{\Delta E_{range}}{E} = \frac{z \cdot \cos\theta}{R \cdot \sin^2\theta}$$

Setup at XCS at LCLS – February 2016

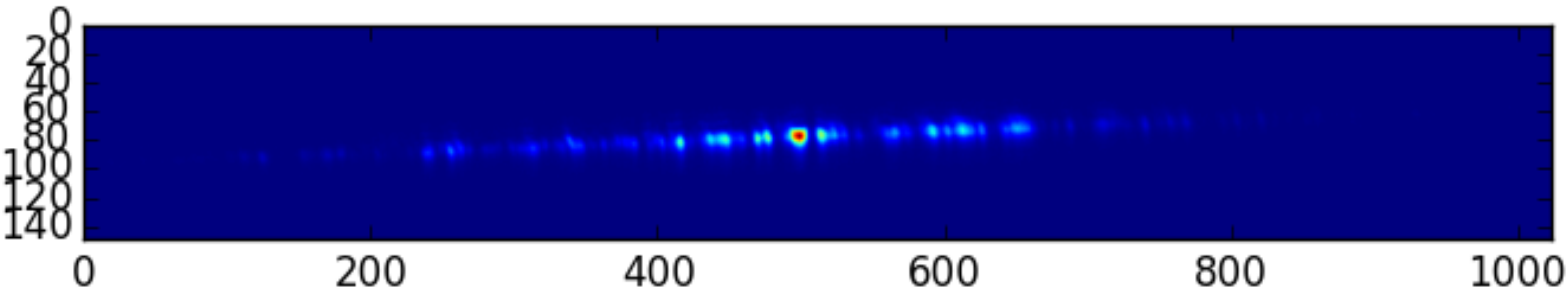




Experiment parameters

- Comparison C*(220) with Si(220) and later Si(440) at 7.6 keV
- Further C*(440) measured at 10.5 keV
- C* analyzer: thickness 20 μm, R~0.1m
- Si analyzer: thickness 10 μm, R ~ 0.05 m
- Pink SASE beam, 180pC bunch charge, 33fs pulse duration
- 120Hz repetition rate
- Beamsize ~ 500 × 500 μm
- 2D cameras with scintilator screens, ~5 μm spatial resolution
- Experiments performed at the XCS instrument @ LCLS

Yes, it works!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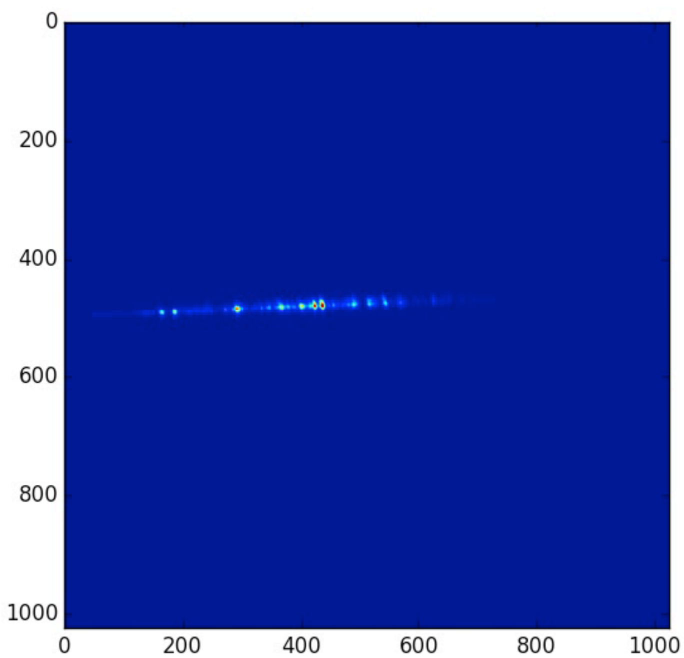
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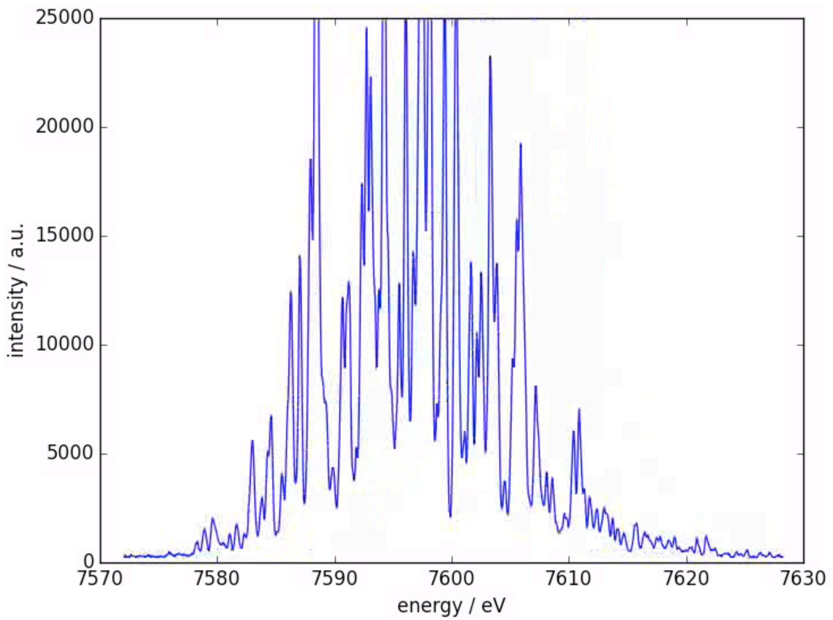
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10000
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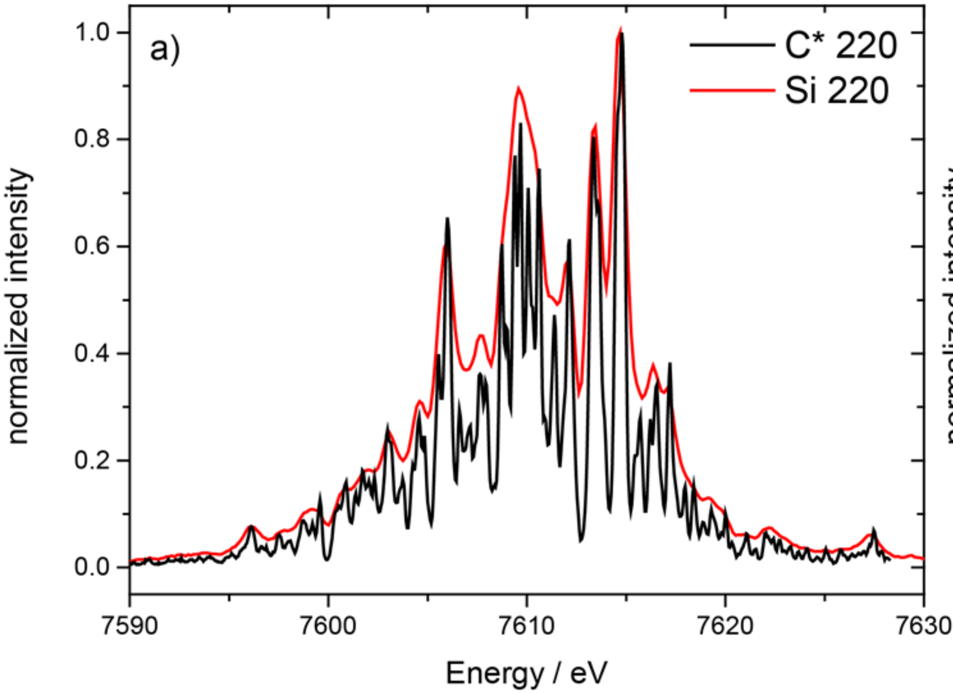
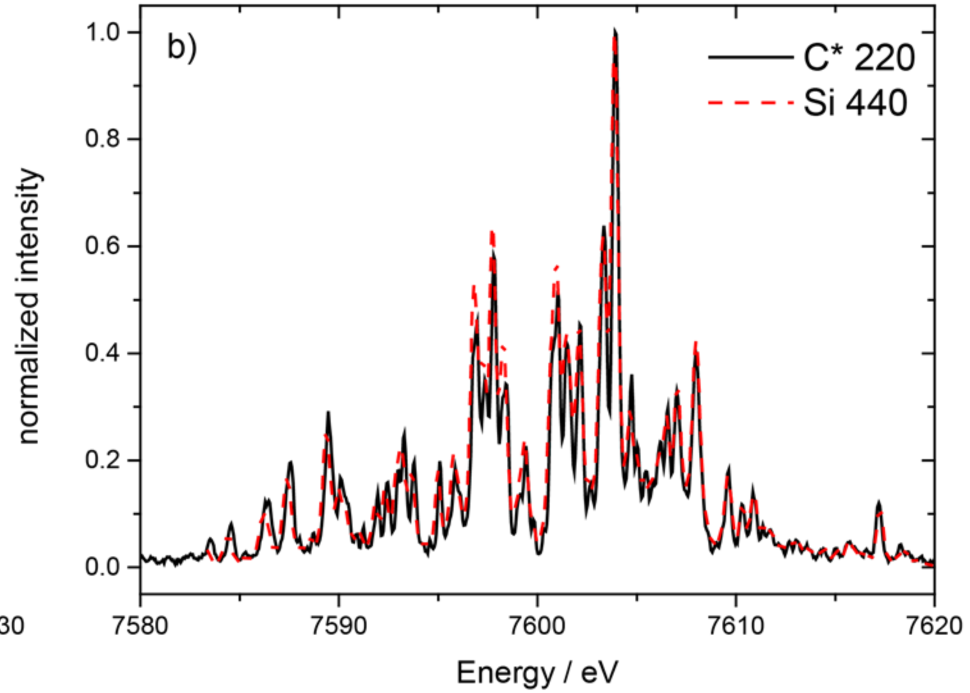
7580
7590
7600
7610
7620
7630
energy / eV

European XFEL

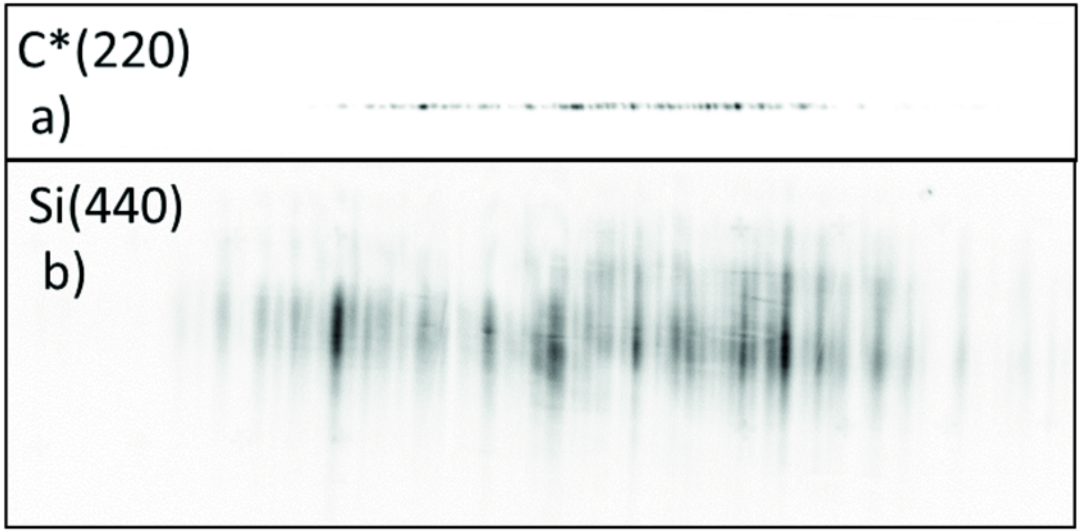
Energy resolution - orientation

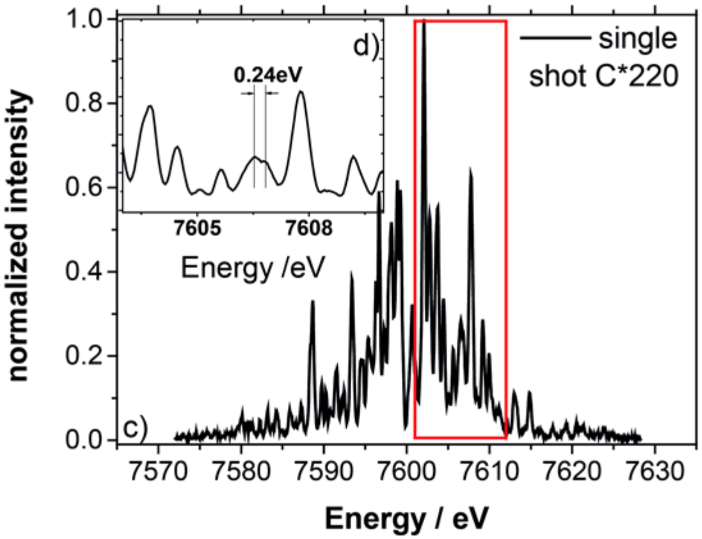




- Si(220) resolution much coarser than C*(220)
- Si(440) resolution similar to C*(220)
- No effective change in energy resolution with changing the bending radius was observed

Energy resolution - spectral features

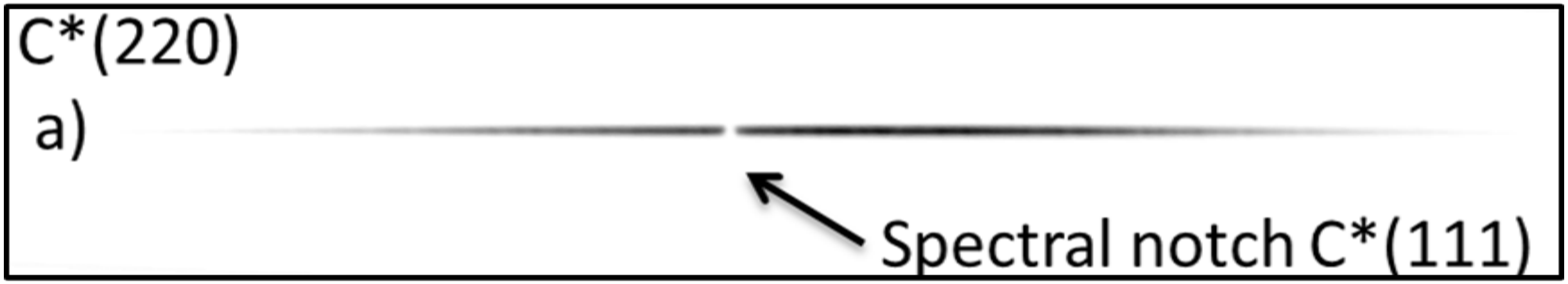




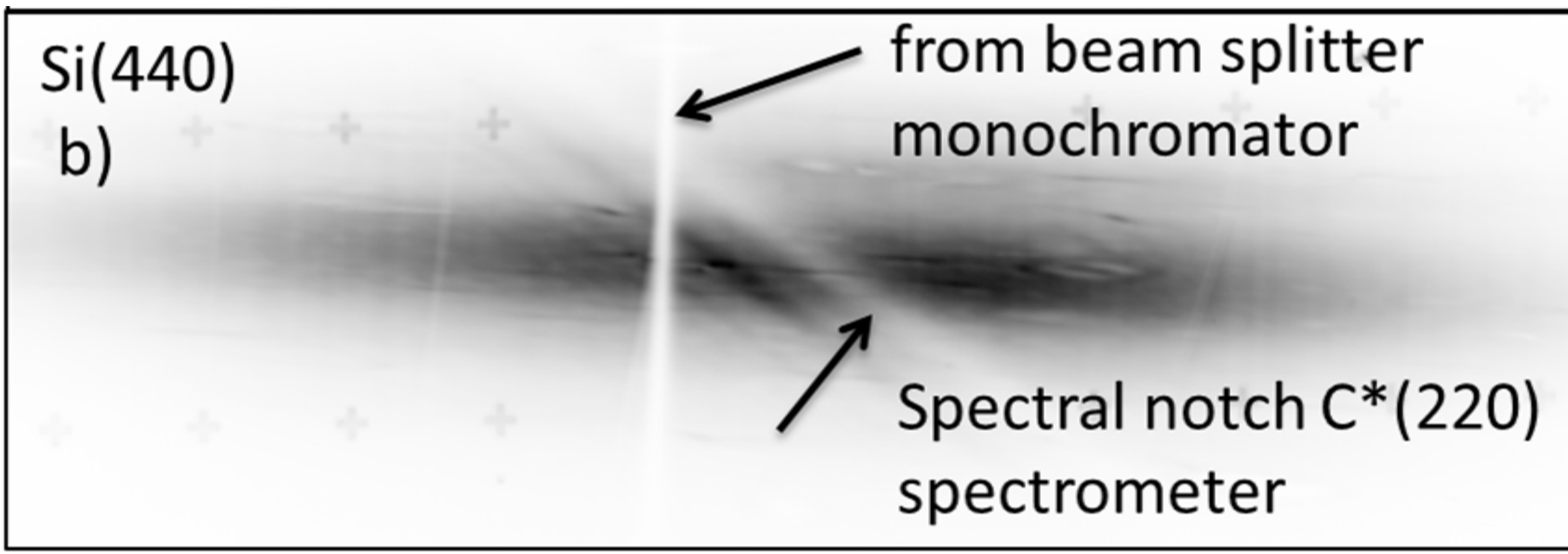
Analyzer crystal	Darwin width Analyzer (eV)	δE (pixel res.) (eV)	δE_{eff} (eV)	measured resolution (eV)
C*(220)	0.15	0.055	0.16	0.24
C*(440) (10.5 keV)	0.031	0.034	0.046	0.32
Si(220)	0.44	0.14	0.46	0.61
Si(440)	0.069	0.039	0.079	0.32

European XFEL

Averaged images



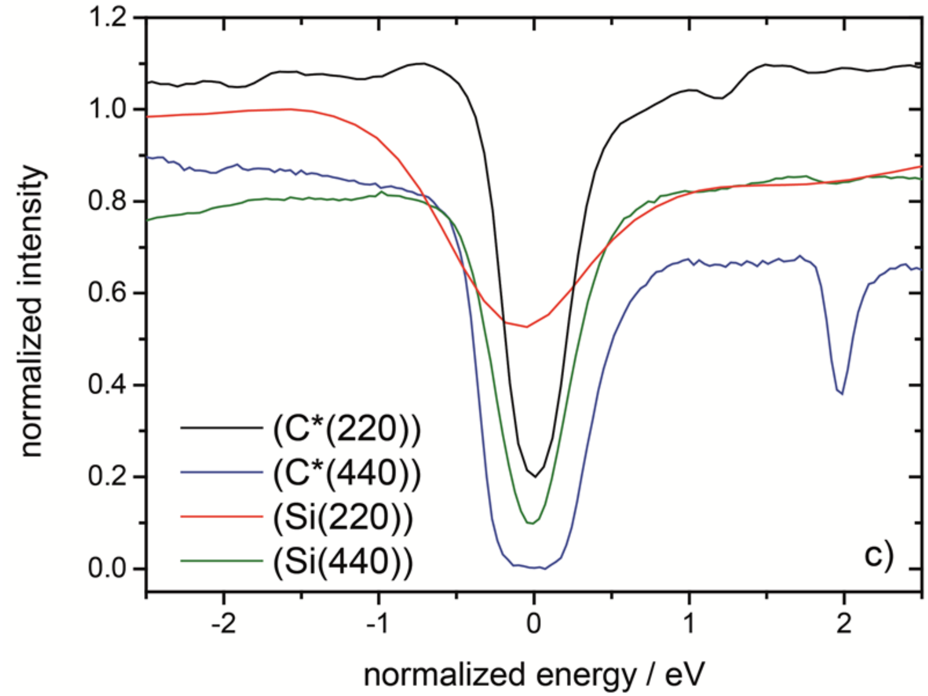
- Sum over C*(220) images, the ‘notch’ is due to upstream C*111 beam-splitter
- Focussing due to sagital bending of the analyzer crystal



- Sum over Si*(220) images, 1. ‘notch’ due to beamsplitter, 2. caused by the diamond spectrometer

Energy resolution - notch-width

- Introducing the C*(111) beam-splitter monochromator of XPP
- Comparing the expected and measured width of the notch to describe the energy resolution.



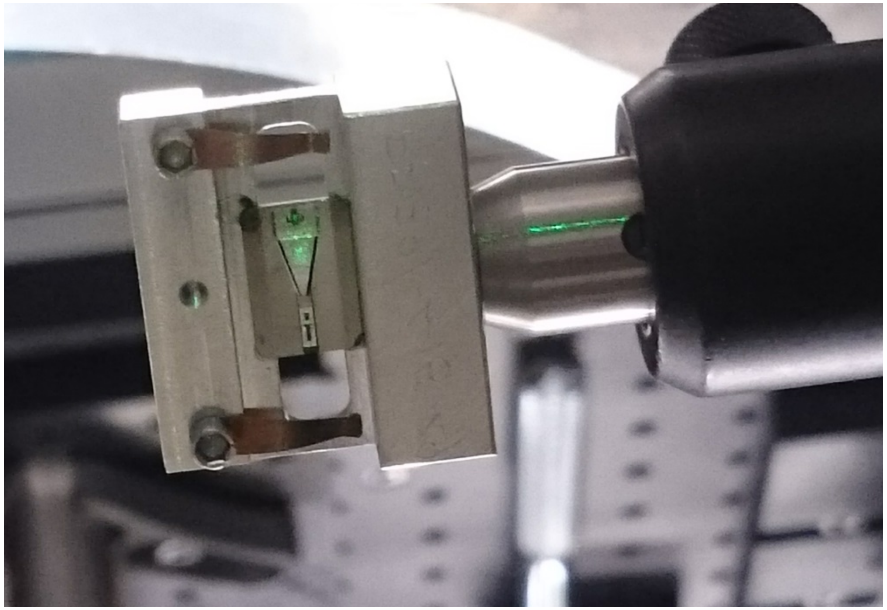
Analyzer crystal	δE_{eff} (eV)	Darwin width C* 111 (eV)	Expected width (eV)	Measured width (eV)	Deviation
C*(220)	0.16	0.45	0.47	0.48	2.1%
C*(440) (10.5keV)	0.046	0.62	0.62	0.71	14.5%
Si (220)	0.46	0.45	0.64	1.0	56.3%
Si (440)	0.079	0.45	0.45	0.56	24.4%

Comparison to future EU.XFEL setup

- LCLS: FOV=5mm, assuming: distance 0.35m, 1024 pixels of 5μm.
  - This would be similar to ~15mm FOV at 1m distance.
- XFEL with a Gotthard I detector: FOV=64mm, distance 1m, 1280 pixels of 50μm.
  - The full bandwidth should be covered
  - Theoretical pixel resolution is 0.216 eV for C*(220) at 7.6 keV for 50 μm pixels (Si (220) @ LCSL was 0.14 eV).
  - For C*(440) at 10.5keV calculated pixel resolution is 0.092eV for 50 μm pixels (@ LCSL measured 0.034 eV)

Summary and conclusions

- Successful measurements with a bent-diamond spectrometer in transmission geometry at LCLS
- Direct comparison to in-line bent-Si spectrometer
- Two orientations (C*(220), C*(440)) tested and two different bending radii
- The ultra-thin diamond device is much more stable in vacuum than previously measured Si crystals (Feng et al, JPCS 425, 2013).



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Vladimir Blank

Thank you for your attention!!!!