Status of the Hard X-ray Self-Seeding Project at the European XFEL

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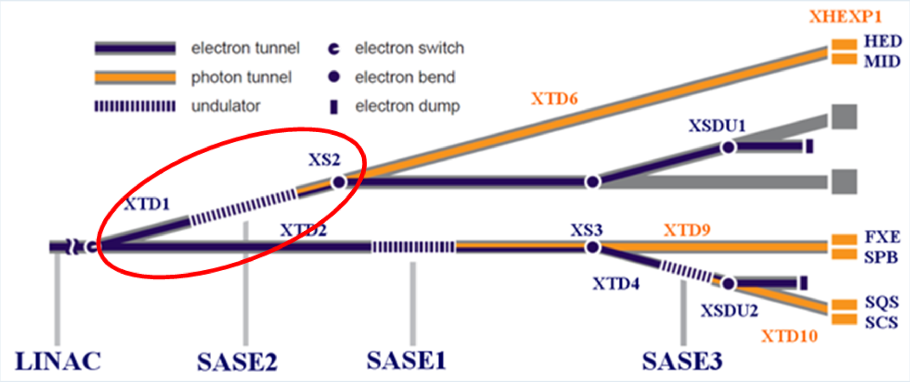
HXRSS Position and layout

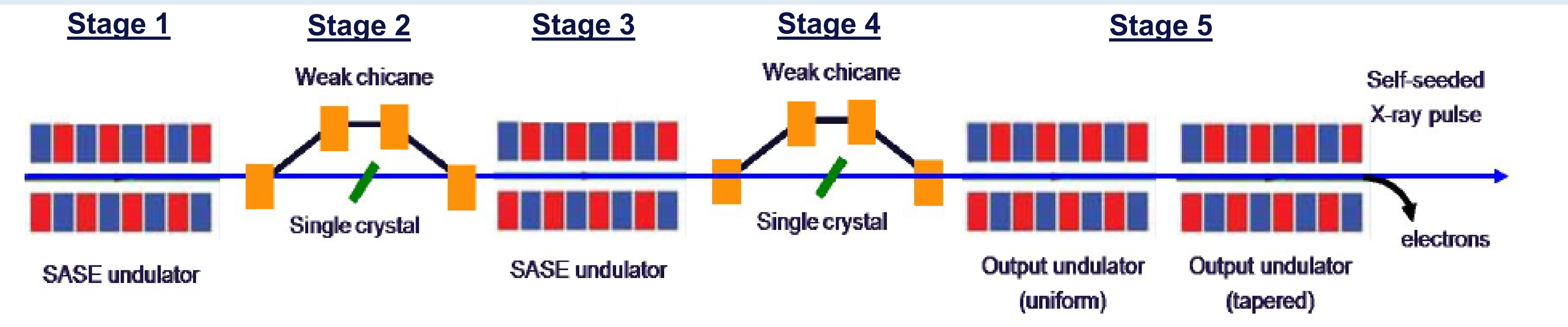
A Hard X-ray Self-Seeding setup is currently under realization at the European XFEL, and will be ready for installation in 2018.

The SASE2 hard X-ray line (3keV-25keV) will be the first to be equipped with HXRSS. Specific for the European XFEL:

- High repetition-rate
- Long undulators



Design based on a 2-chicane scheme

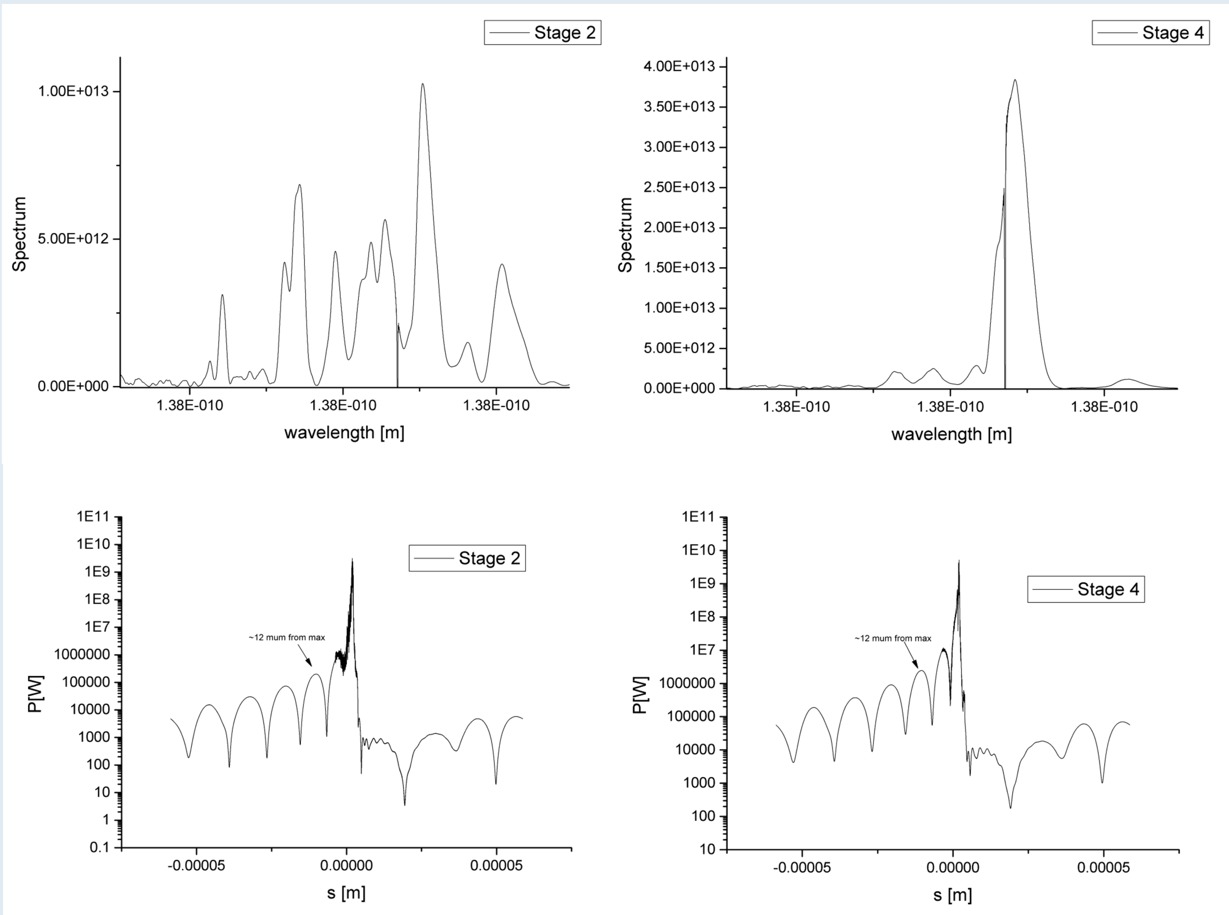


Increases signal-to-noise ratio by the ratio of SASE/seeded bandwidths

The undulators in Stage1 and Stage3 have the same magnetic lengths.

Stage4 suffers from poor S/N ratio but is almost Fourier limited

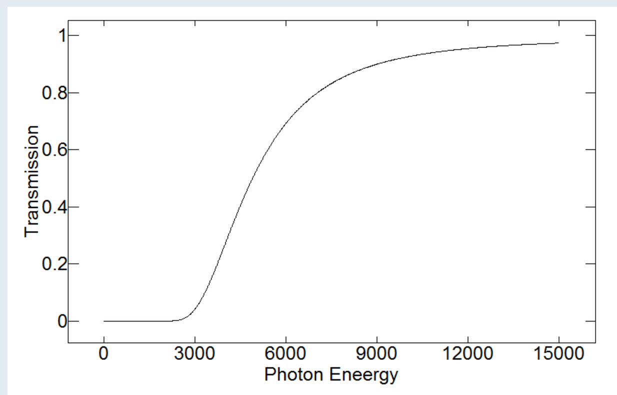
The seed signal in the time-domain is much better in Stage 4, compared to Stage 2



The 2-chicane scheme can be used to ease the heat-loading from the SASE/seeded signals, which depends on the fundamental.

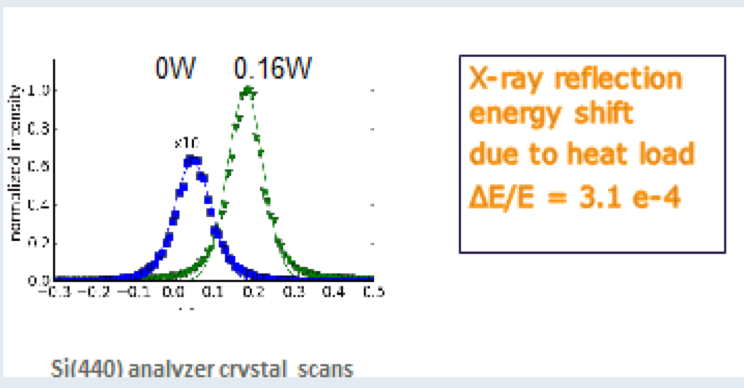
Pulse heats up crystal locally→slow heat diffusion w.r.t. rep. rate →T increase

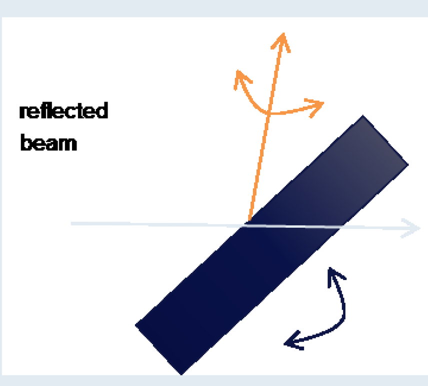
- ω-shift beyond Darwin width→Spectrum broadening (can tolerate a few times more)
- Example: 100mm, C*400; 3μJ/pulse (0.7 μJ absorbed) incident at 8keV within the reflection BW in 1000 pulses
- 3.3keV: deposited 90%: 0.8μJ/pulse incident



Heat-loading from the spontaneous signal: broad spectrum

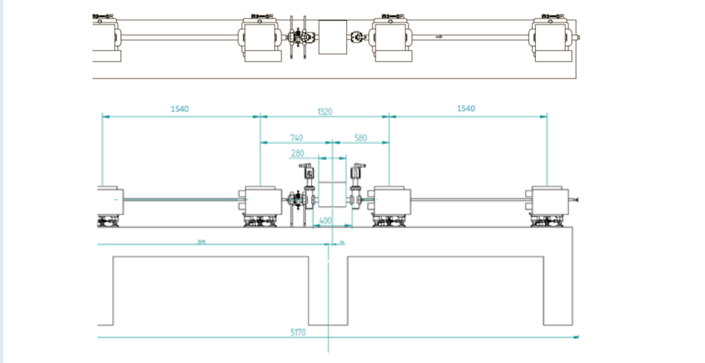
- Total energy deposition for 8 segments,100pC, 17.5GeV, 100μm crystal ~ 6μJ
- Effect of X-ray reflection enrgey shift was experimentally observed
- Pitch oscillator treated as an option to ease the spontaneous radiation heat-load (space foreseen/some development within mono design contract) → oscillate Bragg Angle to compensate temperature cycle during pulse train



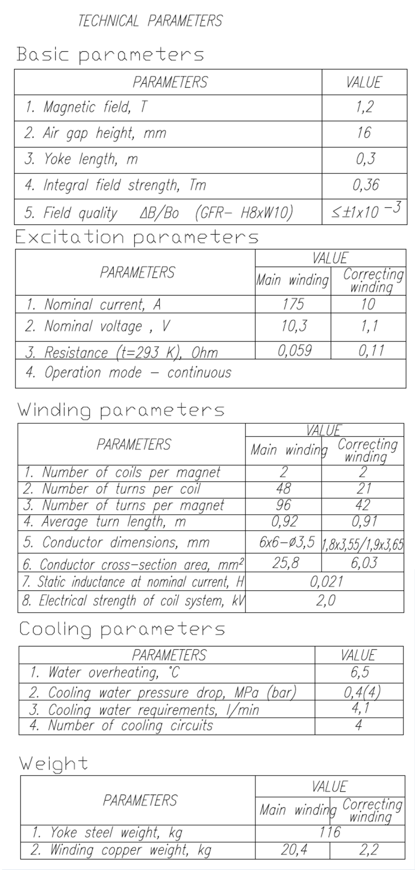


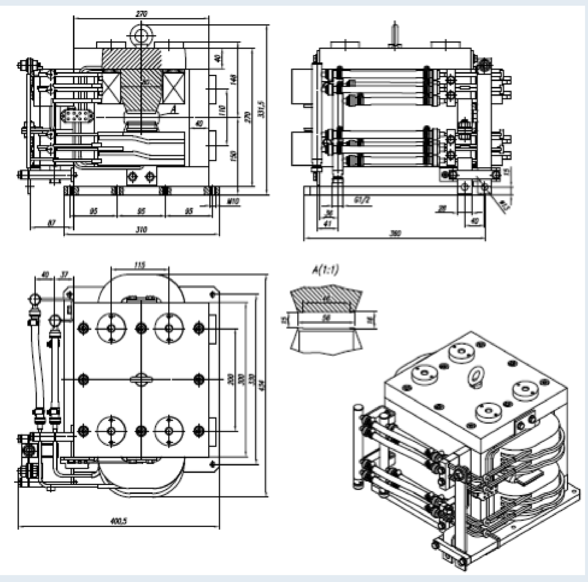
Frequency (Hz)	Angular Range (PV)
1200	70 urad
…	…
300	280 urad
…	…
10	0.48°

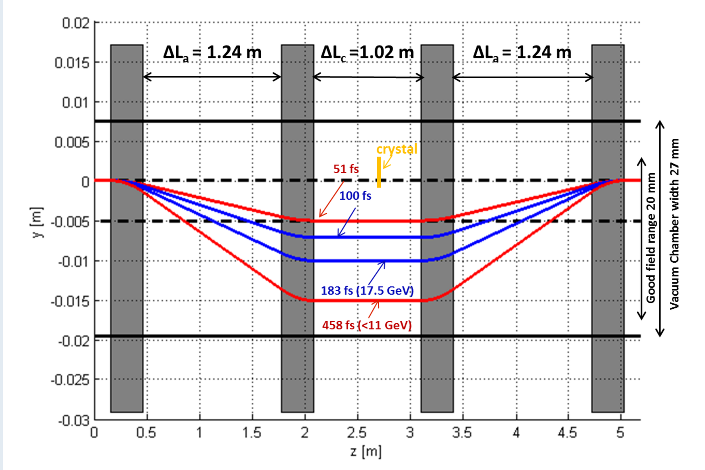
Chicane current status



Parameters	Symbol	Normal	Minimum	Maximum	Unit
Electron beam delay	Δt	51 -100	0	183	fs
Electron beam offset	Δy	5 – 7.2	0	10	mm
Width of good field range	w_g	20	10	-	mm
Deflection angle	ϑ	3.2 – 4.4	0	6.2	mrad
R56	R_{56}	30.4 – 60.0	0	109.5	μm
Dipole field	B_0	0.63 – 0.87	0	1.2	T
Integrated field strength	∫Bdl	0.19 – 0.26	0	0.36	T·m
Magnet yoke length	L_b	0.3	-	-	m
Magnet vertical gap	g	16	-	-	mm
Vacuum chamber width	w	27	-	-	mm
Distance between outer and inner magnets	ΔL_a	1.24	-	-	m
Distance between inner magnets	ΔL_c	1.02	-	-	m
Nominal current	I	175	-	-	A

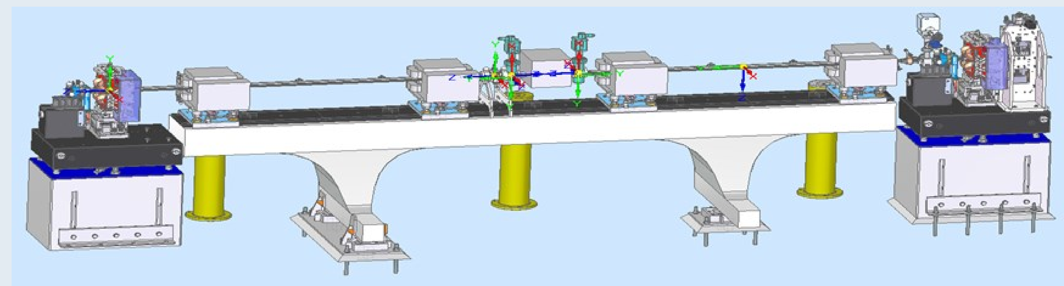






8 H-type dipole magnets ready (May 2017)

Setup (no mono) ready:



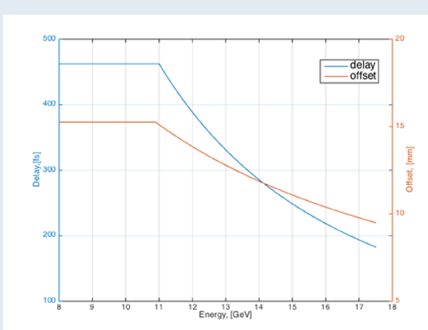
Delay steps: 0.1 fs for autocorrelation → power supply requirements

$$\langle P(t)\rangle = P_0 \exp\left[2L_w \mathrm{Re}(\Lambda(t))\right]$$ [redacted]

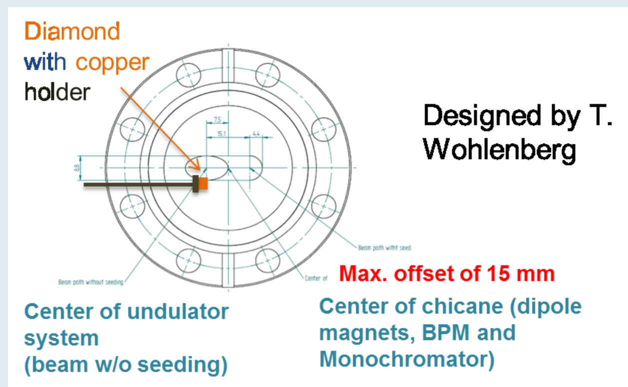
$$\langle P_2(t,\tau)\rangle = \langle P(t-\tau)\rangle \exp\left[2L_w \mathrm{Re}(\Lambda(t))\right] = \frac{1}{P_0}\langle P(t-\tau)\rangle \langle P(t)\rangle$$

Power supply	Type	Max. Current	Resolution	Stability
Main coil	Bipolar	200 A	1/20 bit (~10^{-6} of max. current)	10^{-6}~10^{-5} (in hours)
Trim coil	Bipolar	10 A	1/18 bit (~4×10^{-6} of max. current)	~10^{-4} (in months)

Maximum delay: as large as possible for two-color applications



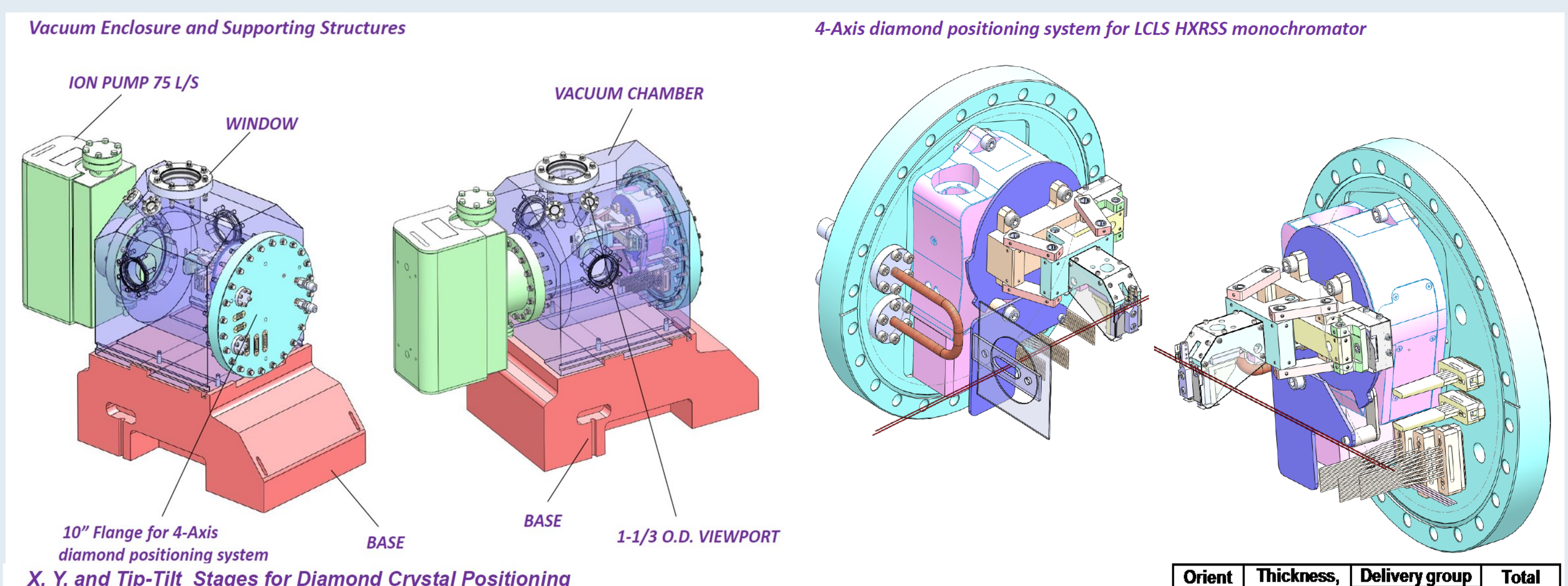
B_{max}=1.2 T Δy_{max}=15 mm



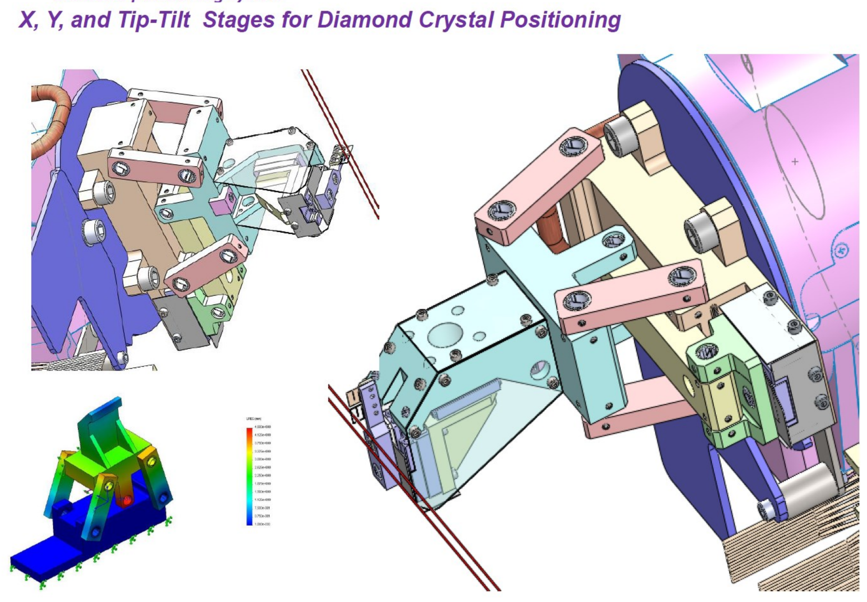
A shift of 7.5 mm is applied to chicane chamber center -> both the dipole magnets and the BPMs are shifted by 7.5 mm to insure a maximum offset of 15 mm

Minimum delay: depends on beam-halo; simulations indicate that 2mm might be reachable

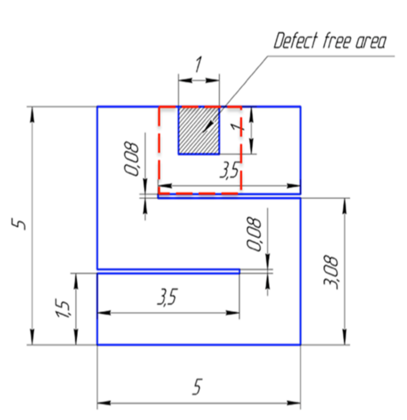
Monochromator design



X, Y, and Tip-Tilt Stages for Diamond Crystal Positioning



Diamond Specifications



Orientation	Thickness, μm	Delivery group I	II	III	IV	Total Amount
100	100±10	2		1	1	4
100	160±10	2		1		3
110	100±10		2		1	3
111	100±10			2	1	3
111	50±10		2		1	3

Requirements to diamond plates:

- HTHP IIa type
- Crystallographic orientation 100, 110, and 111, with azimuthal orientations aligned with main crystallographic directions
- Size 5 x 5 mm, see drawing on Fig.1
- Defect-free area extended from 1 x 1 mm on the top (Fig. 1, blue line) to 2 x 2 mm (red dashed).
- Less than 5 μm thickness variation
- Misorientation less than 0.5 deg

Requirements to the holders:

- Made of vacuum and e-beam compatible material
- Should provide deformation-free mounting the diamond crystal plates, max deformation of the top area 10^{-5}
- Should remove ~1W at nitrogen (100K) temperature of the crystal
- The holder design must be agreed between with D. Shu and TISNCM