Superconducting THz undulator for FLASH

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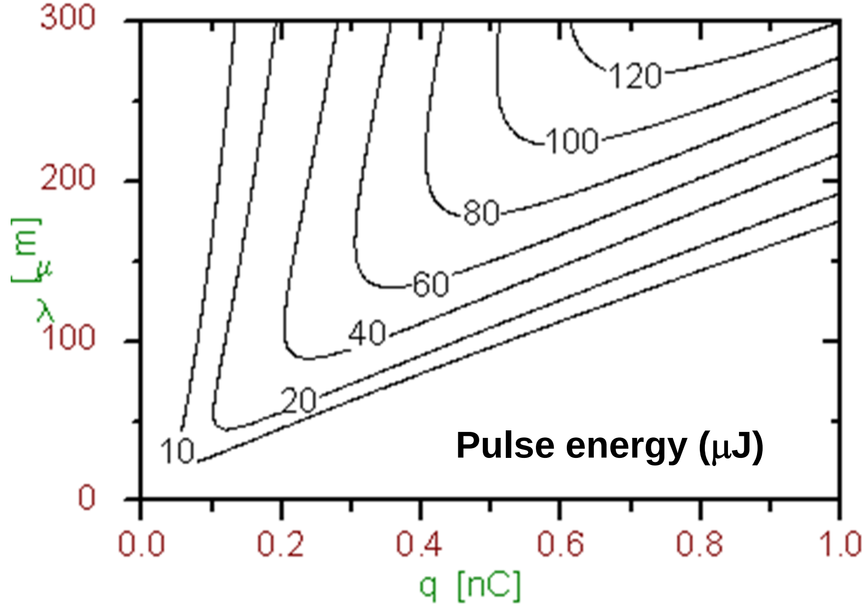
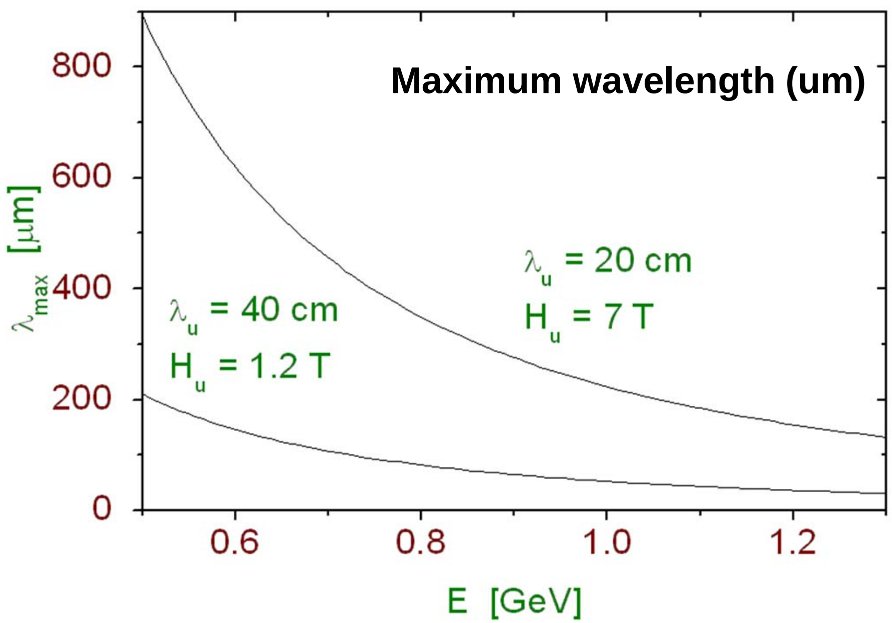
Motivation:

- Extension of the THz wavelength range.
- More compact device.
- Reduction of operational cost.

SC undulator for FLASH





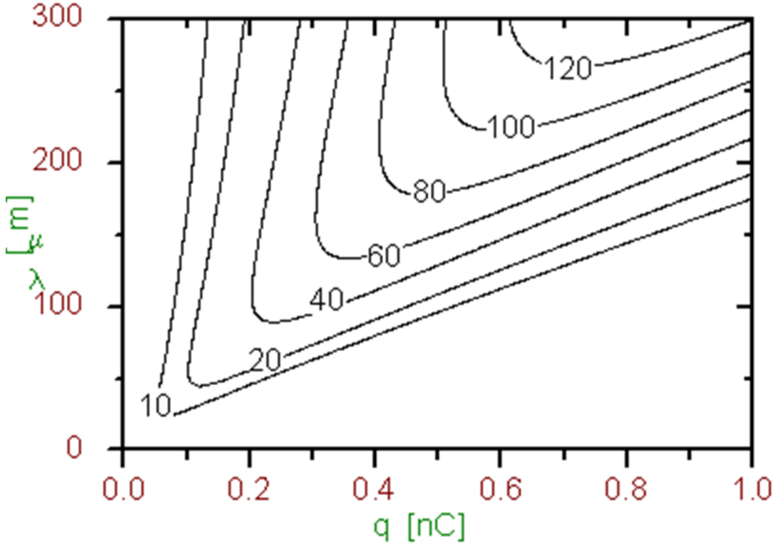
- Operating wavelength range is extended by a factor of 4 with respect to present EM undulator.
- Physical mechanism for the increase of the radiation power remains the same:

$$\langle P(\omega)\rangle = p(\omega)[N + N(N-1)|\bar{F}(\omega)|^2] \ ,$$

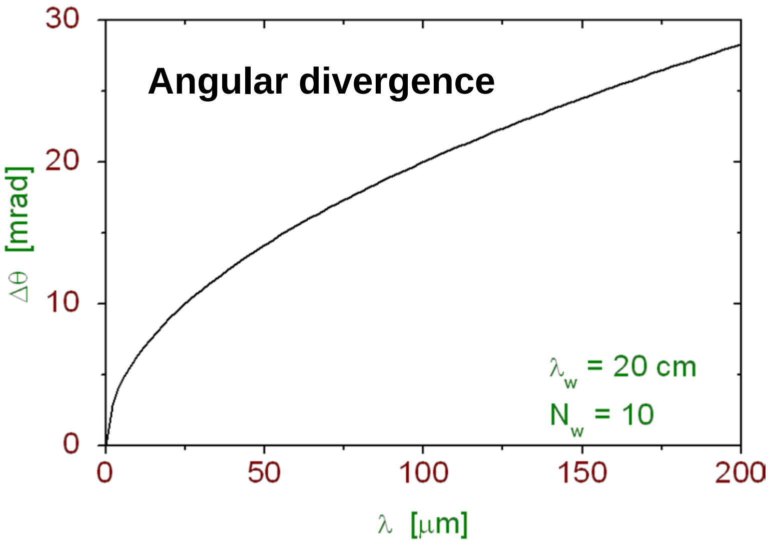
- For an electron beam with Gaussian distribution of the current profile we have:

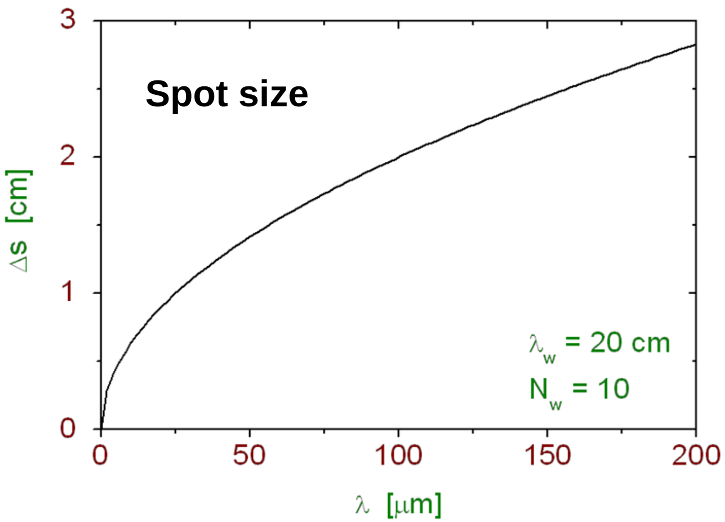
$$F(t) = \frac{1}{\sqrt{2\pi}\sigma_z} \exp\left(-\frac{c^2t^2}{2\sigma_z^2}\right) \ , \qquad \bar{F}(\omega) = \exp\left(-\frac{\omega^2\sigma_z^2}{2c^2}\right) \ .$$

SC undulator for FLASH



Radiation characteristics at longer wavelengths will be corrected by waveguide effects in the vacuum chamber of the undulator





BINP: 30 years of experience in SC insertion devices

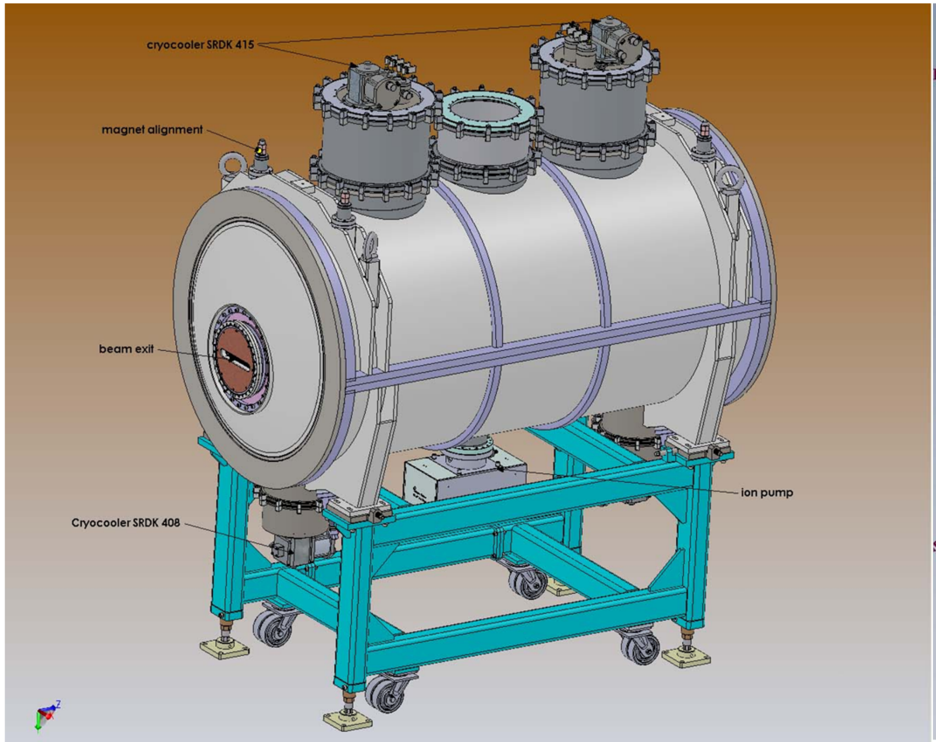
SR Center	Year	Maximum magnetic field, T	Number of poles (Main + Side)	Magnetic gap, mm	Main pole length, mm	Magnet length, mm	Vertical aperture, mm	Radiation power, kW	Electron energy, GeV
VEPP-3 (BINP)	1979	3.5	20	15	45	900	8	2.8	2
Undulator(BINP)	1984	0.47	16	18	12	250	13	-	0.65
VEPP-2 (BINP)	1984	8	5	26.5	120	600	15	-	0.65
Siberia-1 (Moscow)	1985	5.8 (4.5)	1+2	32	-	350	22	-	0.45
PLS (Korea)	1995	7.68 (7.5)	1+2	48	170	800	26	3.6	2
LSU-CAMD (USA)	1998	7.55 (7)	1+2	51	172	972	32	5.3	1.5
SPring-8 (Japan)	2000	10.3 (10)	1+2	40	200	1042	20	100	8
BAM-WLS (BESSY-II)	2000	7.5 (7)	1+2	52	172	972	32	13	1.9
PSF-WLS (BESSY-II)	2001	7.5 (7)	1+2	52	172	972	32	13	1.9
HMI-MPW (BESSY-II)	2002	7.67 (7)	13+4	19	74	1360	14	60	1.9
ELETTRA (Italy)	2002	3.7 (3.5)	45+4	16.5	32	1680	11	8.8	2
CLS (Canada)	2005	2.2 (2.0)	61+2	13.5	17	1120	9.5	12	2.9
DLS (UK)	2006	3.8 (3.5)	45+4	16.4	30	1544	10	50	3
Siberia-2 (Moscow)	2007	7.7 (7.5)	19+2	20.4	82	1836	14	110	2.5
CLS-2 (Canada)	2007	4.3 (4.0)	25+2	14	24	1000	9.5	10	2.9
LNLS (Brazil)	2009	4.1	31+4	18.2	30	1162	14	4.4	1.37
DLS-2 (UK)	2009	4.2	45+4	14	24	1304	13.8	-	3
ALBA-CELLS (Spain)	2010	2.2	117+2	12.6	15.1	1892	8.5	-	3

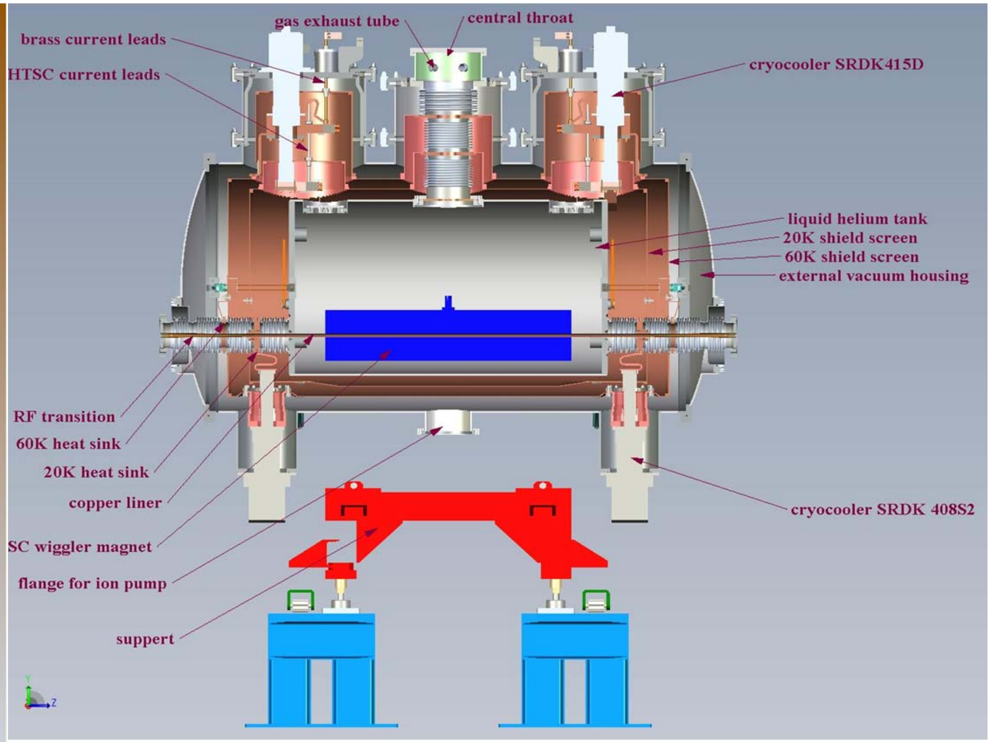
Device developed for LSU-CAMD (period 20 cm, number of periods 10, peak field 7.5 T) fits well as THz source for FLASH

SC undulator for FLASH

Field Direction	Vertical
Nominal peak on axis field, B_o	7.5 T
Maximum peak on axis field	7.7 T
Period length	200 mm
Number of pole pairs @ full field	11
Number of pole pairs @ ¼ field	2
Number of pole pairs @ ¾ field	2
Field sequence	¼, -¾, 1, -1, 1… 1, -¾, ¼
Pole gap	25.2 mm
Currents	150 A + 190 A
Stored energy (field 7.5 Tesla)	~850 kJ
Aperture	15 mm x 80 mm
Ramping time, 0 to nominal peak field, up or down	≤ 15 min
External dimensions of the cryostat (length, width, height)	2300x1200x2550 mm

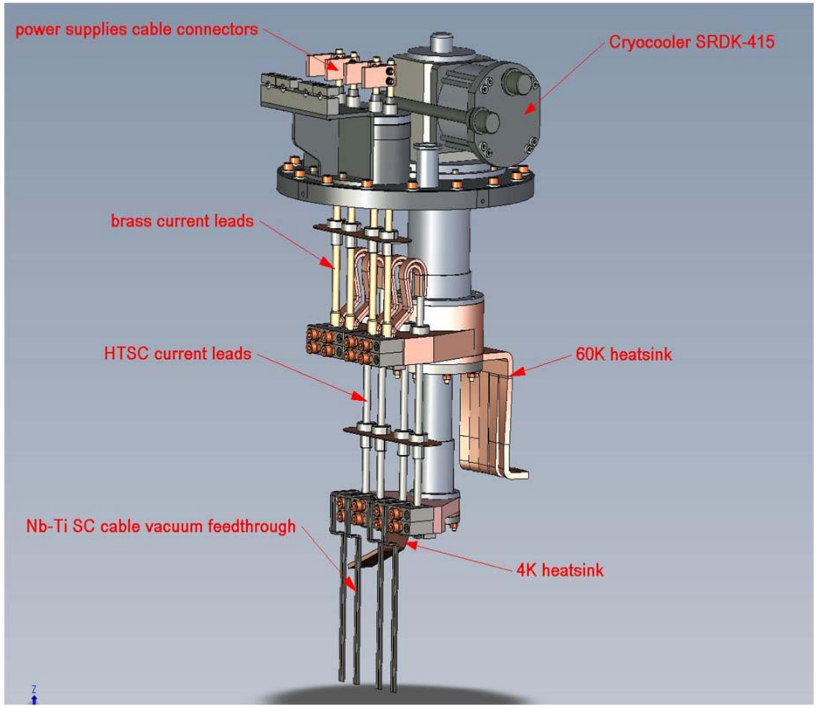
SC undulator for FLASH





Schematic layout of SC undulator and cryostat with integrated cryocoolers

SC undulator for FLASH

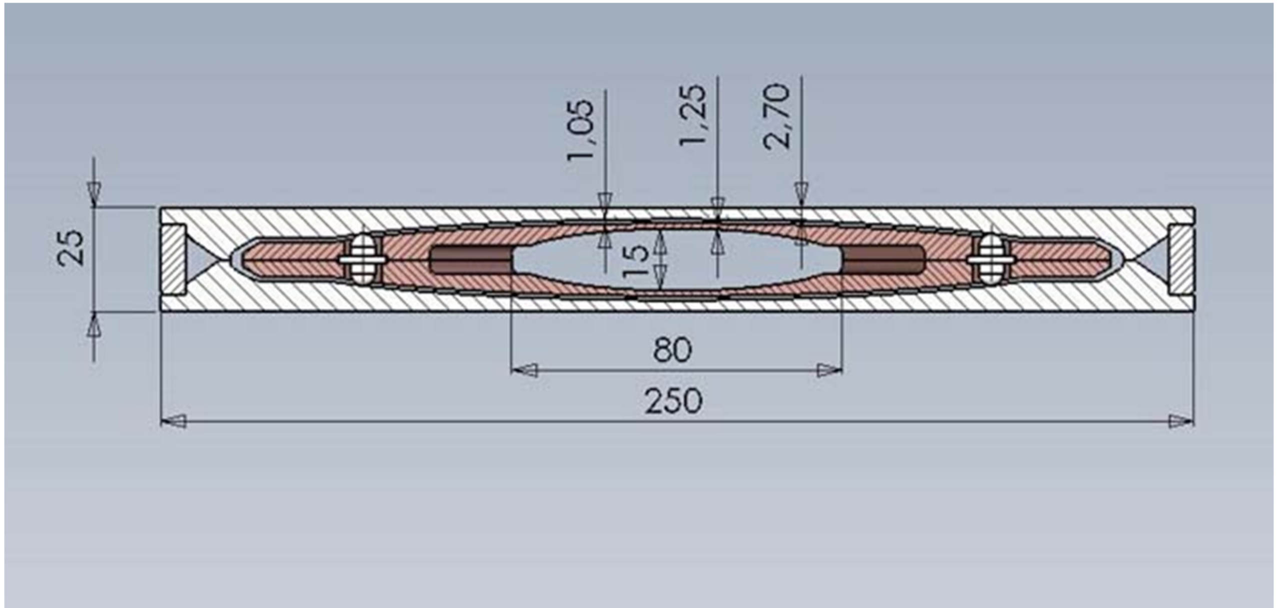


Example of design : Current leads block

Design includes all modern trends:

- Two-section windings of NbTi wire to optimize field strength.
- Control the field integral to zero with two power supply units (for the central and side coils).
- Minimization of the heat leaks and Joule heating includes special design of current leads block, application of HTSC, cold welding of the connections, etc.
- Application of cryocoolers allows to organize closed loop operation with low liquid helium consumption.
- Application of passive and active systems for quench protection and energy extraction.

SC undulator for FLASH



Vacuum chamber

Summary (1)

SC undulator is an attractive option:

- Factor of 4 extension of the wavelength range with respect to present EM undulator.
- Factor of 2 shorter than present EM undulator.
- Much less power consumption: a few kW versus 100 kW with present EM undulator.
- No need in the significant amount of cooling water for undulator windings, just moderate cooling of power supply.
- Design with cryocoolers integrated with cryostat allows long term autonomous operation with rare refilling procedures.

Draft of the technical proposal is available on request.

Summary Table

We just recently started consideration of an option of superconducting THz undulator for FLASH. Currently we find it to be attractive from both, scientific and technical point of view. However, an extended expertise is required including accelerator and photon physics experts, and technical services at DESY/FLASH. Thus, specific dates can not be filled in the summary table.

- Title of the project: Superconducting THz undulator for FLASH;
- Involved institutes: DESY, BINP (Novosibirsk);
- Main hardware changes required for existing FLASH facility: about 3-4 meters of free space in the FLASH/FLASH2 beamline (after the main undulator) for installation of cryostat with SC undulator;
- Estimated time needed for hardware changes / installations: 2 weeks for installation. Time slot can be combined with other works.
- Estimated beam time required for commissioning: 10 shifts.