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PolFEL - NEW FACILITY IN POLAND*

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Abstract

PolFEL will be first free electron laser in the part of eastern Europe, Poland. The source of low energy linac will be superconducting photocathode. PolFel will operate in CW and long pulse (lp) mode. PolFEL will generate THz, IR and VIS-VUV radiation. PolFEL is going to prepare number of end-stations for user activities. The most unique end-station base on Inverse Compton Scattering phenomena will allow to perform measurements with X-ray photons with time resolution in fs range.

PolFEL DESCRIPTION

In this short document the main parameters of PolFEL are mentioned. In last three decades Polish scientists and engineers participated in and contributed to many projects related to Free Electron Laser- and High Energy Physics facilities worldwide, not having any of these facilities in the country. Therefore, group of Polish scientific institutes interested in the modern research with coherent radiation was very pleased receiving in 2018 funds for the free electron laser PolFEL project from the Smart Growth Operational Programme, Measure 4.2: Development of modern research infrastructure of the science sector.

A PolFEL consortium was established with NCBJ as project leader and eight Polish research institutes and universities as members. PolFEL will be driven by cw operating superconducting linac with SRF electron source developed in collaboration with DESY and 8 superconducting TESLA cavities housed in 4 Rossendorf type cryomodules. Moreover, accebility of new superconducting technology enabled us to designed state-of –art linear accelerator operating both in the continuous wave (cw) mode and long pulse (lp) mode. The cw mode allows for full flexibility of electron beam time structure and hence photon beams. Time structure (max repetition rate 50 KHz) is defined by laser beam irradiating the cathode in a superconducting injector (SRF injector). The injector cryomodule for PolFEL contains one 1.3 GHz SRF 1.5-cell cavity made of nobium. Designing of this cryomodule base on the conceptual design from DESY is a part of project and cryomodule will be made at NCBJ. Cavity is housed in a titanium helium vessel in temperature range 1,8 – 2,0 K. Thermal shielding is the most crucial system, will include two lines of the helium (2 K, 5 K) and Liquid Nitrogen. The PolFEL project has received already significant hardware support from the STFC Daresbury Laboratory, e.g. components of a 120 W@2K cryogenic plant, many beam optics components and RF-components. The cryogenic system design is in charge of specialist from Wroclaw University of Science and Technology. PolFEL will generate THz, IR radiation and VIS-VUV radiation in two beam lines, respectively. In the first one, with electron beam below 80 MeV, the THz/IR radiation source will be generated in permanent magnet supper-radiant undulator, delivering THz radiation in 0.5–3 THz range. IR undulators will be positioned upstream THz undulators. In the second beam line with up to 180 MeV electrons, the VIS/VUV radiation will be generated in the SASE undulator delivering coherent radiation down to 55 nm in the third harmonic. Both undulators will be based on the modified Bazin design shared by the STFC Daresbury Lab and assisting the NCBJ team in the modification effort. Both undulators are going to be made in NCBJ.

PolFEL parameters are written in Table 1 and Table 2.

Table 1: PolFEL Electron Beam Parameters

	Unit	Gun	VUV /electron line	THz line
Bunch charge	pC	20-250	max 100	250
Bunch repetition rate	kHz	50	50	50
Transvers normalized 80% slice emittance	μm·rad	0.1-0.4	< 0.5	<0.75
Bunch duration at the electron line exit	ps	2-10	0.4	up to 10
Beam energy at the line exit: cw mode lp mode @ duty factor of 40%	MeV	4	90-154 up to 187	up to 65
Maximal beam current	μA	12.5	5	12.5
Beam power at dump: cw lp @ duty factor of 40%	W	-	650 374	813

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Table 2: PolFEL Photon Beam Parameters

	Unit	VUV (1st Harm.)	VUV (3rd Harm.)	THz line
Min wave length: cw lp @ DF=40%	nm	210 165	70 55	(0.5 - 6)·10^5 (0.5-6 THz)
Energy per pulse, $E_γ$: cw lp @ DF=40%	µJ	75.0 19.6	0.22 0.03	30
Radiation power: cw lp @ DF=40%	W	3.75 0.40	0.01 0.0006	1.5
Pulse duration	ps	0.35	0.35	30
$ΔE_γ / E_γ$	-	0.008	0.008	0.05

The construction of the experimental end-stations receives much attention in the project. At the moment, four end-stations are planned based on the scientific case developed during meetings with potential users. PolFel will gives opportunity to adopt time parameters on user demands. Photons parameters will be monitored during run time with diagnostic systems. The experimental setup will allow for studies of physical and chemical properties of solid states, gases, and liquid samples facility is going to provide a infrastructure for studies of life samples. The facility will be equipped with optical laser system with OPA, which parameters will allow for repetition rate from single shot to max. 50 kHz The three wavelengths 1030 nm, 515 nm and 257 nm and OPA tuneable range from 190 nm to 16 µm will be available. Users will have access to experiments equipped with dedicated Pump-Probe spectrometer in whole range of photon radiation. The end-stations are designed in cooperation with experimental groups from Institute of Biochemistry and Biophysics Polish Academy of Sciences and Military University of Technology. For The UV beamline beam leaving the SASE undulator is going to contain two spectral components - the fundamental wavelength of 255/165 nm and its third harmonic at 85/55 nm, depending on the working regime (CW/pulsed). The output photon beam diameter from source is calculated as 0.1 mm and the estimated divergence equal to 0.5 mrad. Giving estimated beam diameter in the first steering mirror chamber (~10 m) of about 5 mm. One of proposed solution for diagnostic purpose is separating the fundamental and third harmonics by a thin foil filter, however most likely of customized diffraction grating out-coupling a few percent of the incident energy is going to used. The main part of energy (more than 90 %) will be directed in the zeroth order along the path determined by the axis. It is assumed that the grating designed for the 3rd harmonic will not distort the wavefront of the beam at the fundamental frequency. The second method even if more expensive and complicated has the advantage that the wavefronts of the separated waves will be influenced in a very limited degree. There are no pellicle beam-splitter of nanometer thickness and flatness conserving the wavefront quality at reflection. The final diameter of the beam spot on the sample in experimental chamber will be of 20 µm. Beam spectrum will be monitored on the shot-to-shot basis even in the case of assumed reproducibility of the energetically stable emission. The measurement of the temporal shape requires very specific tools and here it is planned to develop such a method based on secondary effects of interaction, e.g. ionization. The energy level or the photon flux delivered in the beam will be monitored by GDM together with the support for controlling the beam positioning relative to the assumed optical path. GMD is going to be designed with help of FLASH /DESY advisory.

In addition to already known application of VUV like ablation or desorption, in the spectral range of the PolFEL most of the solid materials show very short attenuation, in extreme cases going down to significantly less than 100 nm. Combination of moderate focusing and the minimum absorption depth make density of the absorbed energy to be higher than the high energy density limit (HED), recently redefined as 104 J/cm3. This would open an unexpected field of interest and very attractive research branch. The beamlines in the terahertz photon energies region starting from 0.5 THz allows for examination of matter properties not observed so far. End-stations will be equipped to perform experiments in the magnetic field of low temperature samples, (absorption and emission spectroscopy in wide sample temperature range(LHe-HT), gases, liquids, molecules, solids). Experience from specialist of the MUT in the THz imaging technology is going to be important factor to design THZ imaging end-station (2D or 3D) in PolFEL. Separated experimental station will be devoted to Life Science experiments. This station will operate in the whole radiation range provided by PolFEL.

Specially designed system will conduct IR, UV and THz radiation to entrance of Life Science beamline. In addition the pump-probe experiment will be available. At presence the main experimental method offered to the user will base on the commercially provided stopped-flow apparatus (Fig.1).

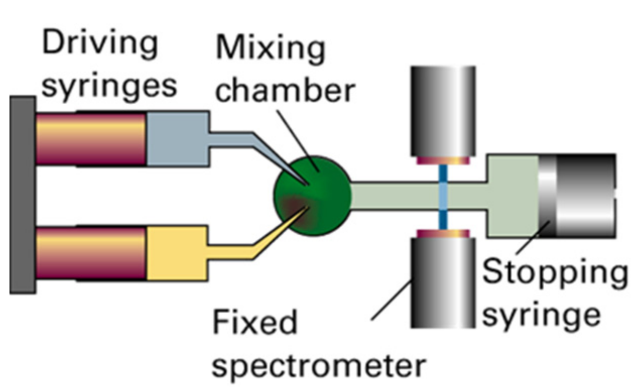

Figure 1: Geometry of the stopped flow apparatus.

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The exceptional end-station base on Inverse Compton Scattering phenomena will allow to perform measurements with X-ray photons with time resolution in fs range.

CONCLUSION

This short document describes parameters of PolFEL the free-electron laser to be construct in Poland, by the end of 2022. Authors would like to thank to FEL community especially HZDR, HZB, DESY ELLETRA/FEL and STFC for discussions and valuable attention.