STATUS OF THE FEL PROJECT AT NILPRP*

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Abstract

Scientific research in Romania is currently experiencing a growth period, due to increasing national founding and wider international involvement. Many research and development institutes have upgraded their research infrastructure in the last years initiating long-term projects. However, the scientific community still lacks FEL/synchrotron-based infrastructure depending on the beam time allocated at laboratories across Europe. This article presents a tentative proposal for a single-pass seeded FEL which might be the basis of a national laboratory. The project shall be soon launched into debate at national level. The choice of the FEL scheme and auxiliary infrastructure has to be a compromise between the requirement to have a competitive and versatile machine and the need to use mature technologies while keeping the costs at a reasonable level. A seeded FEL [1,2] operating in the VUV/soft X regime is thought taking benefit of the local tradition in using laser systems and experience in building and operating electron linacs. Excellent coherence and short pulse duration are two definitive advantages that the FEL radiation has over the classical undulator radiation. This will make the current project extremely useful for users, coming from a large variety of fields. While significant work has to be carried in the up-coming years in order to set accurate working parameters, the goal here is to share the initiative to the accelerator community for a critical review.

PRELIMINARY LAYOUT AND SPECIFICATIONS

For the time being, the project is not yet properly defined but a few key parameters for the first stage can be given within a certain tolerance. In order to become a modern research tool the first experimental line shall count on the following important radiation characteristics:

- Brilliance in the order of 10^{30} *ph/s*/mrad^2/mm^2/*0.1* % *b.w.*
- FWHM radiation pulses of 400-500 *fs*.
- Minimum radiation wavelength within the 150 – 50 *nm* range.

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Taking benefit of the in-house know-how [3], the RF injector will be designed to yield ps-pulses with a total charge in the range of 0.5-1 nC. See Fig. 1 for a simplified view of the machine. The electron bunches will be immediately accelerated and bunched in order to minimize the losses due to the unavoidable space-charge. A key parameter is thus the rms normalized transverse emittance when the beam exits the injector (≈50 MeV) and by emittance correction techniques [4] it shall be kept around 1-2 *mm−mrad*. Repetition rate has to be set following upcoming debates regarding the scientific relevance of the project. Follow ing further acceleration up to around 250 MeV the electron bunches will be magnetically compressed such that their duration falls within the *fs*-range. Several compression schemes will be envisaged so that a certain flexibility is allowed to the FEL system and consequently to the users. The four linac modules shall be fed by high powe S-band klystrons providing a few MW peak power, using the SLED technology in order to double the peak voltage, at the expense of the power pulse duration.

After being collimated the beam enters the undulator region (modulator and radiator) where the interaction with the seed laser occurs. The seed laser should operate in the 200-250 *nm* range, delivering ps pulses of a few tens of *MW*, synchronously and collinearly with the electron bunches. The seed power has to be optimized as a compromise between the need to minimize the induced energy spread and the necessity to overpass the shot noise. With λ_s the seed laser wavelength $K_{mod/rad}$ and $\lambda_{mod/rad}$ respectively the modulator/radiator strength and period, the resonance condition enabling the gain is:

$$\lambda_s = \lambda_{\mathrm{mod}/rad} \frac{1+K^2_{\mathrm{mod}/rad}}{2\gamma^2} \tag{1}$$

However, the interplay of the laser beam and undulator field becomes effective if λ_s is slightly off-resonance enabling an energy modulation within the electron bunches. This energy modulation turns into a density modulation as the beam advances through the dispersive section and so the premises for a coherent radiative process are fulfilled. There will be strong coherent bursts distributed at the higher harmonics of λ_s, with the cut-off harmonic number defined as the ratio of the energy modulation to the energy spread of the electron beam.

The modulator will consist of a short plane undulator while the radiator will be helical undulator, both of Apple II type [5]. This way the polarization of the amplified radiation can be conveniently controlled. In-house experience in numerical modelling of undulators [6] shall be used for this purpose. Key aspects are to optimize the undulators strength in compliance with the resonance condition (1), keep the magnetic forces under control and design correction coils for the undulators end. The dispersive section will act as well as a phase shifter so that the arrival of the bunched electrons into the modulator can be delayed, making them transfer energy to the laser beam (gain). Additionally, a short wiggler may be interposed between the modulator and the radiator, if bunching efficiency needs to be increased.

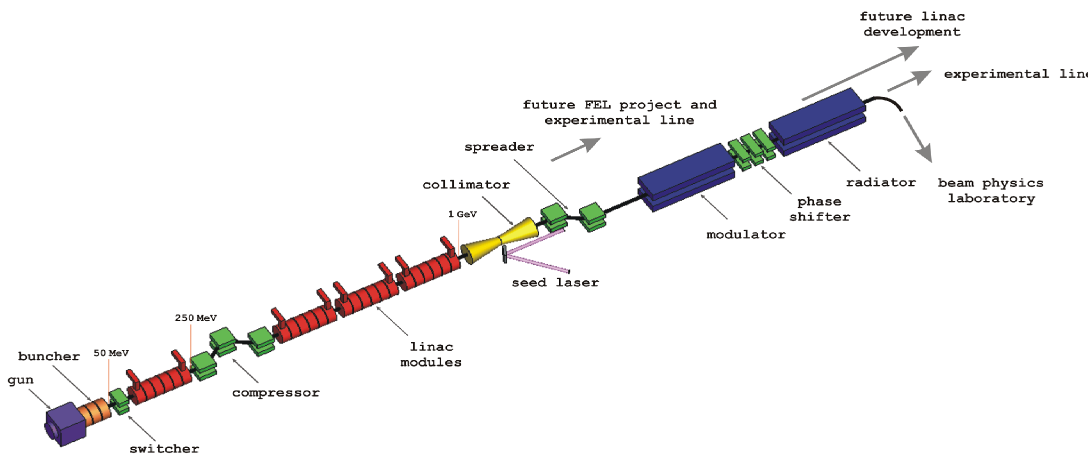

Figure 1: Simplified layout of the machine.

CONCLUSIONS

Finally, Table 1 summarizes important parameters for the electron beam, modulator and radiator obtained through the resonance condition (1) applied to the seed laser and to its 3rd harmonic, respectively. Some of the parameters presented above have been concluded renewing a previous proposal for a FEL project based on one of the NILPRP linacs [7]. In the upcoming months the project proposal will be refined in more details and launched into national competitions for funding. The success however, depends largely on the commitment of the Romanian scientific community and on the international collaboration.

The first stage of the project will end with the commissioning of the first experimental line operating in the VUV range and start of the user program. With experience acquired during the operation of this line a second stage will be the development of new laser systems for seeding at even lower frequencies so that a new FEL line can be designed for wavelengths approaching within the soft X-ray range.

Table 1: Review of the preliminary machine parameters

Parameter	**Value**
Electron beam	
Nominal beam energy, E	0.75-1 GeV
Normalized beam emittance, $\epsilon_{x,y}$	1-2 $mm-mrad$
Bunch length, l_b	400-500 fs
Bunch charge, Q	0.5-1 nC
Beam size (rms), $\sigma_{x,y}$	250-300 μm
Peak beam current, $\hat{I}$	1 kA
Seeded Free Electron Laser	
Seed laser wavelength, λ_s	200-250 nm
Modulator peak field, $\hat{B}_y^{mod}$	1 T
Modulator periodicity, λ_{mod}	5.6-6 cm
Modulator strength, K_{mod}	5.23-5.6
Radiator peak field (circ.pol.), $\hat{B}_{x,y}^{rad}$	0.7 T
Radiator periodicity, λ_{rad}	4.4-4.7 cm
Radiator strength, K_{rad}	3.28-3.5
Emitted wavelength (3rd harmonic) λ_e	67-83 nm
Emitted peak power, $\hat{P}_e$	1-2 GW

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