THE ELBE-PROJECT AT DRESDEN-ROSSENDORF

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Abstract

The Forschungszentrum Rossendorf (FZR) is building a superconducting linear accelerator which will deliver a cw beam of 1 mA electrons with 40 MeV. Different electron guns are under development. Additionally to the production of secondary radiation as X-rays, bremsstrahlung, neutrons and positrons, special emphasis will be put on the production of intensive FEL radiation in the IR wavelength range of 5 to 150 micrometers. For the longest wavelengths an electromagnetic undulator is under development, whereas for the shorter wavelengths permanent magnet devices will be installed. Several user labs for the optical beam are built.

1 THE ELBE ACCELERATOR

At the Forschungszentrum Rossendorf (FZR) a superconducting electron linear accelerator (ELBE) is being built. It will deliver a maximum electron energy of 40 MeV and a mean beam current of up to 1 mA. The construction of the ELBE building and the caves for housing the accelerator and the experimental equipment has been completed, and the accelerator is expected to deliver a first electron beam within the year 2001.

2.1 Injector

The different requirements resulting from the planned experiments are accomplished by an electronically grid-pulsed thermionic gun, which could be operated in different modes. A further macro pulser allows a very flexible time structure of the beam. The gun is operated at 250 kV. Bunch compression for injection in the first LINAC is done by 2 bunchers operating at 260 MHz and 1.3 GHz. For future use with a as small as possible transversal emittance a different type of injector is needed. A different gun for this injector is in development.

2.2 Beam Transport

The beam transport to the Free Electron Lasers (FEL) will be done with a S-shaped beamline. This design gives an achromatic beam transport with constant bunch compression (R_{56}). A variable bunch compression will be done with a variable chicane after the first LINAC. The other beam lines to the nuclear physics experiments are also achromatic.

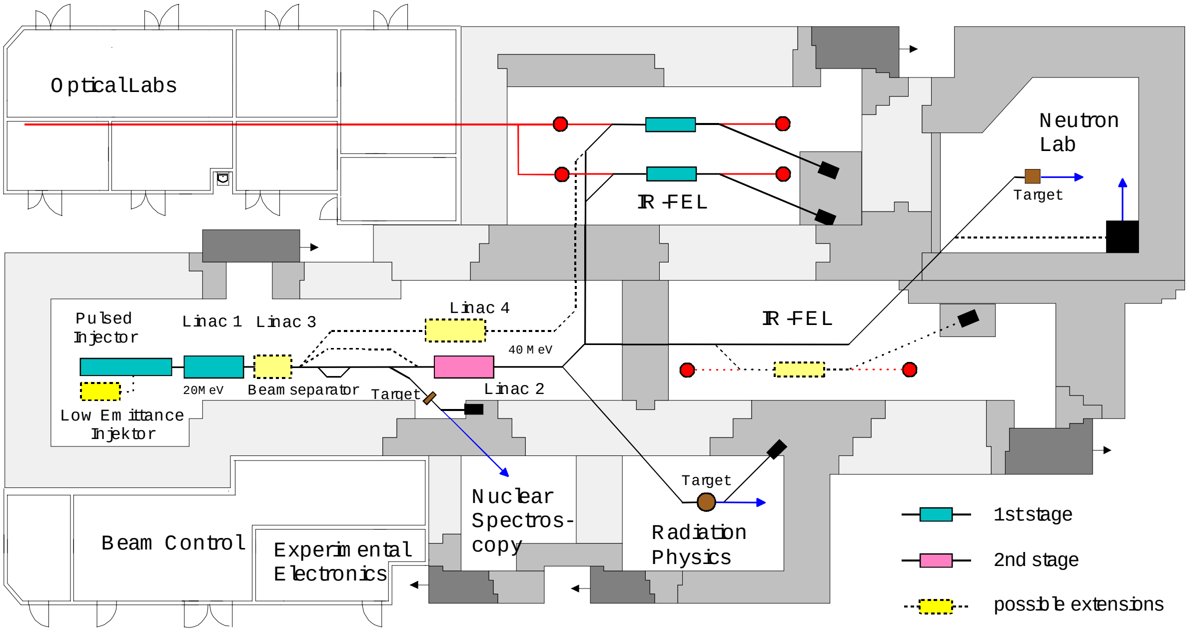

Figure 1: Beamline layout of the ELBE facility

Table 1: Accelerator requirements

Operational mode	FEL, Nuclear Physics	Radiation Physics
Mean beam current	1 mA	0.1 mA
Bunch charge	77 pC	0.4 pC
Transverse emittance	20 mm mrad	3 mm mrad
Beam energy	10..40 MeV	15..40 MeV
Energy spread	90 keV	90 keV
Micropulse frequency	13 MHz	260 MHz

2.3 Main accelerator

The main accelerator uses standing wave RF-cavities at 1.3 GHz from DESY. The cavities are superconducting Niobium structures, which are operated at 2 K in liquid Helium. The accelerating gradient is higher than 15 MV/m. Every cavity is driven by a 10 kW klystron amplifier.

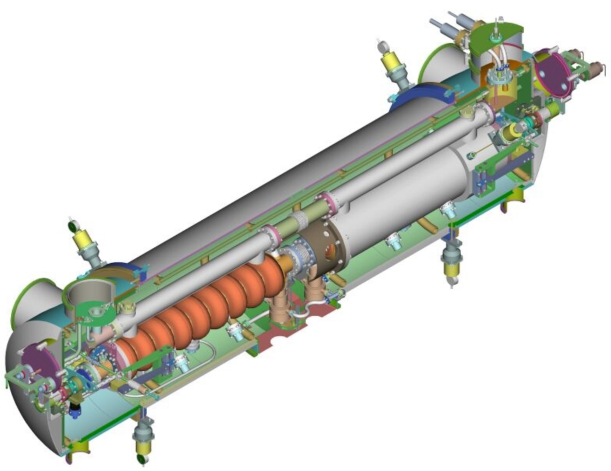

Figure 2: Cryostat with 2 cavities

2 A TUNABLE QUASI-MONOCHROMATIC X-RAY SOURCE

At reduced intensity ELBE allows a low divergence electron beam to be used for the production of X-rays via the following methods:

- Channeling radiation will have energies from 10 keV to 50 keV
- Compton backscattering of optical or infrared photons results in X-ray energies from 0.3 to 20 keV

Two other processes may be of interest as well:

- Parametric X-rays range in energy from 2 keV to 40 keV
- Transition radiation has $E_\gamma \sim 1$ keV

All these processes produce X-rays in a narrow energy band. Besides the high intensity the tunability of the X-ray energy and the flexible timing of the pulsed beam make these radiation sources versatile tools for all kinds of experiments. Quasi-monochromatic X-rays of variable energy appear to be an ideal probe for the elementary processes responsible for radiation damage in living cells. A special feature at a superconducting accelerator like ELBE is the wide variability in pulse sequence in combination with a time resolution below 10 ps.

3 NUCLEAR PHYSICS EXPERIMENTS AT ELBE

High intensity bremsstrahlung may be produced by the electron beam and in two step processes also short neutron pulses can be generated. The good time resolution of ELBE (< 100 ps) allows small flightpath time-of-flight experiments with variable pulse separation (75 ns to seconds). Energy dependent neutron cross section measurements of importance for fusion and fission reactor technology can be performed as well as triggered fission studies for the spectroscopy of neutron-rich medium-mass nuclei. Inelastic photon scattering (nuclear resonance fluorescence, NRF) is a very powerful means for the spectroscopy of stable nuclei, especially when making use of polarized bremsstrahlung as envisaged for ELBE; it allows e.g. to determine the parity of nuclear excitations.

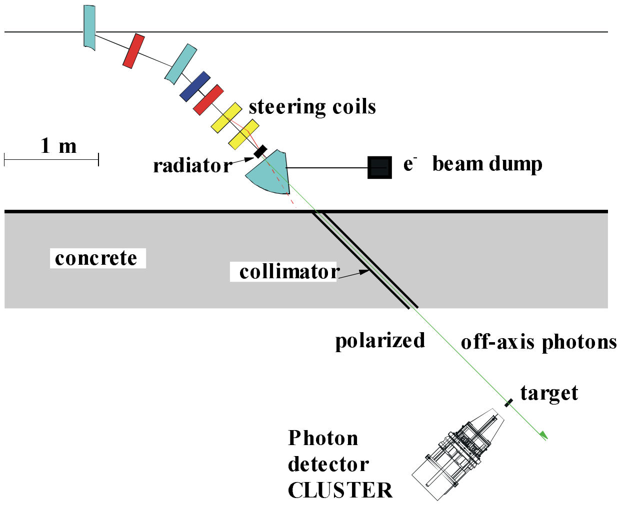

Figure 3: Beam line for Nuclear physics

4 FREE-ELECTRON-LASERS FOR THE FAR AND MID-INFRARED

In Figure 4 a schematic of a Free-Electron-Laser shows its major components. The undulator consists of an array of dipole magnets with alternating polarity and two focusing mirrors form an optical resonator. The undulator magnets give rise to a wiggling motion of the electrons and hence to the emission of coherent synchrotron radiation. The intensity of this spontaneous emission is peaked at series of wavelengths λ_n given by

$\lambda_n = \lambda_u(1+K_{rms}^2)/2n\gamma^2$.

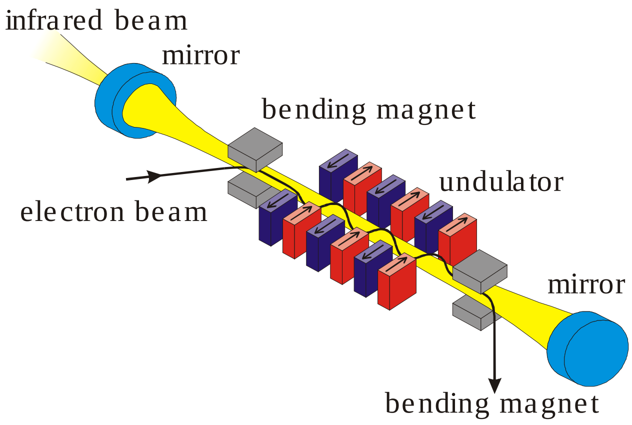

Figure 4: Operating principle of a free-electron laser

The bunch charge (77 pC) of the ELBE electron beam is well suited to drive a FEL system for the production of infrared light in the wavelength region from below 5 µm to above 150 µm. A mid-infrared FEL ranging from 5-20 µm will be based on a hybrid undulator structure consisting of permanent magnets combined with high-permeability iron, designed for the TESLA facility at DESY. A Halbach-type undulator constructed at ENEA/Frascati will cover the wavelength range of 15-150 µm. For the longest wavelengths an electromagnetic undulator to be designed at Rossendorf is considered. Above 30 µm waveguides will be used to compress the optical mode diameter inside the undulator and to minimize diffraction losses.

5 CONCLUSION

The Forschungszentrum Rossendorf is building a superconducting linear accelerator which will deliver a cw beam of 1 mA electrons with 40 MeV. The injector was successful commissioned. The accelerator is expected to deliver a first electron beam within the year 2001. Additionally to the production of secondary radiation as X-rays, bremsstrahlung, neutrons and positrons, special emphasis will be put on the production of intensive FEL radiation in the IR wavelength range of 5 to 150 micrometers. Several nuclear physics experiments are prepared and several user labs for the optical beam are built.

Table 2: FEL-undulators and their radiation

			with 20 MeV		in final state with 40 MeV				
undulator	N	period mm	λ µm	<P> W	λ µm	<P> W	E_{puls} µJ	rate MHz	width ps
U27 x 68 (hybrid, DESY)	68	27	12..20	10	5..20	100	10	13	0.3..3
U50 x 45 (Halbach, ENEA)	45	50	30..150*	5	15..150*	100	10	13	1..10
U90 x 28 (electromagnetic, under discussion)	28	90			20..250*	50	5	13	3..20

15% single pass gain assumed in the calculations

*with a waveguide in the undulator