COMISSIONING OF THE ELBE SUPERCONDUCTING ELECTRON LINAC

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Abstract

The radiation source ELBE at Forschungszentrum Rossendorf is based on a superconducting linear accelerator that produces a cw electron beam up to 40 MeV and 1 mA. In 2001 the first stage of the ELBE-linac was put into operation. The main electron beam parameters like energy, energy spread, transverse emittance and bunch length were determined. Moreover, optimal machine parameters were specified and several online diagnostic tools for ELBE routine high-power operation were tested, such as λ/4-stripline monitors and beam-loss detectors.

1 THE ELBE FACILITY

The heart of the radiation source ELBE is a superconducting Electron Linac with high Brilliance and low Emittance [1]. It will deliver a 40 MeV electron beam wih up to 1 mA cw beam current. A grid-pulsed 250 kV thermionic gun followed by a two-stage RF buch compression serves as injector. Two cryomodules each containing two nine-cell superconducting cavities are operated at 1.8 K. The DESY-TTF-type niobium cavities are driven by 10 kW clystron amplifiers at 1.3 GHz yielding accelerating gradients above 10 MV/m. A magnetic chicane installed between the two accelerator modules allows a further bunch compression down to 1 ps bunch length.

The linac will be used to drive free-electron lasers producing infrared light in the 5-150 μm wavelength region. Additionally, from several conversion targets MeV-bremsstrahlung, X-rays from electron channeling, neutron and even positron beams will be available.

2 ELECTRON BEAM PARAMETERS

During the year 2001 the first stage of the ELBE linac was successfully put into operation. For different modes of oeration optimal machine operating parameters were specified. Main electron beam parameters like energy, energy spread, bunch length and the transverse and longitudinal emittance were measured.

The injector of ELBE operating at β=0.74 to a large part determines the achievable beam parameters. So, the transverse emittance was found to be essentially the same at the accelerator exit as measured inside the injector, mainly governed by the thermionic gun.

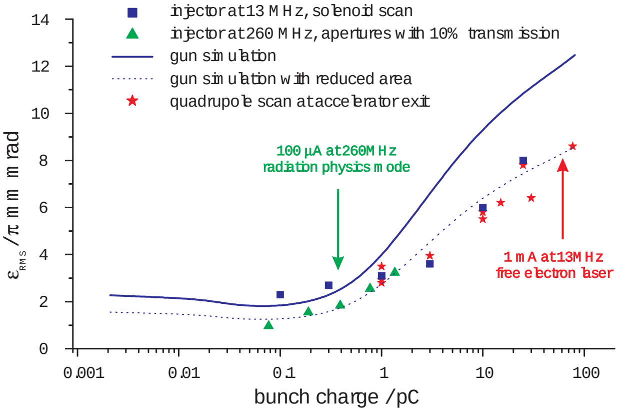

Figure 1: Transverse emittance of the electron beam for varying bunch charges.

The bunch compression in the injector also influences the capture process of the beam into the first accelerator cavity. Therefore, the longitudinal beam parameters as energy spread and bunch length but also the transverse emittance depend sensitively on the relative phase between injector and accelerator RF. At high bunch charges they yield minima at different phases, requiring a compromise for the actual setup.

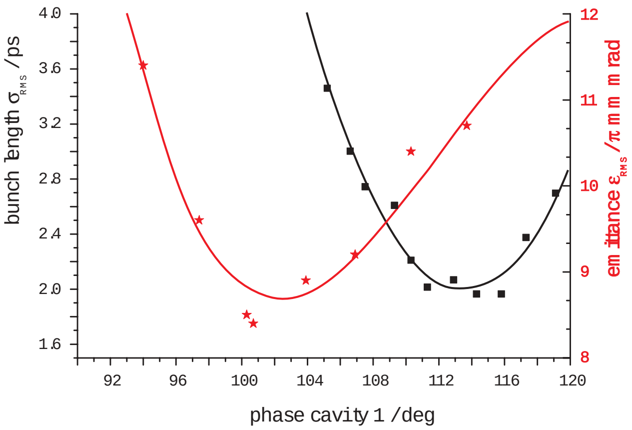

Figure 2: Bunch length and transverse emittance of the electron beam for varying first-cavity RF phase.

The complete longitudinal phase space was mapped using a tomographic reconstruction algorithm applied to energy spectra that were measured while scanning the phase of the second accelerator cavity off the crest of the acceler-

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maximum beam energy maximum beam current maximum bunch charge		20 MeV 0.85 mA at 20 MeV 77 pC	
	at 1 pC bunch charge	at 77 pC bunch charge	
		simultaneously achievable	best achieved
energy spread ΔE_{FWHM} transverse emittance ϵ_{RMS} bunch length σ_{RMS}	35 keV 3 π mm mrad	55 keV 10 π mm mrad 2.5 ps	40 keV 8 π mm mrad 2.0 ps

Table 1: Measured properties of the ELBE electron beam

ating gradient. The longitudinal emittance was found to be approx. 50 π keV ps at 3 pC bunch charge.

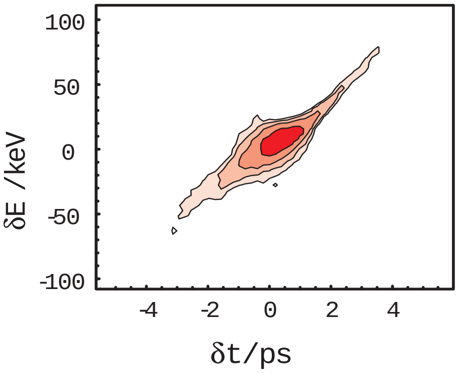

Figure 3: The longitudinal phase space of the electron beam at the exit of the first accelerator cavity.

3 BEAM-LOSS MONITORS

The beam-loss monitoring system at ELBE has to fulfill two different tasks. First, it has to provide a fast signal to the machine interlock system if at any place the beam-loss exceeds a value at which it could damage parts of the beamline or other equipment. Considering that the full beam could hit the pipes, this requires a response time less than 1 ms. Second, it should also provide an information about the amount and the position of low (safe) beam-losses to aid the tuning of the beam transport system.

The system which was tested at ELBE uses long ionisation chambers made of air-insulated RF-power cables. It shows good linearity, a short response time which is only limited by cable capacities and is geometrically well suited to monitor long beamlines. Longitudinal position resolution can be achieved by segmenting the cable.

4 BEAM POSITION MONITORS

For on-line electron beam position control stripline beam position monitors will be used. This type of monitor uses the signals which are induced by the electron bunch on four metal electrodes forming 50 Ω transmission lines. The position of the beam can be calculated from the relative amplitudes of the signals. The signals are filtered to the first harmonic frequency given by the length of the pickup electrodes. After amplification monolithic rms-rectifier chips deliver easily manageable low-bandwidth signals.The position computation is performed with standard analog circuitry or numerically after digitizing all four individual signals.

Figure 4: Design of a λ/4 stripline beam-position monitor.

5 REFERENCES

[1] http://www.fz-rossendorf.de/FWQ/