Linac for a Free-Elcetron-Laser Oscillator; Design Consideration on the Injector System

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ABSTRACT

The specification of a linac dedicated to a free-electron-laser(FEL) oscillator at phase 1 is outlined. Preliminary considerations on the design of the injector system are given.

1. Introduction

At the last meeting at KEK, a long term schedule for FEL study and application at JAERI has been announced. Beçause of the interrelation between the system elements and their parameters, it took rather long to decide on suitable system features of the linac and the accompanying FEL oscillator.

2. Main Feature at Phase 1

FEL oscillators require a train of high-brightness electron beam bunches, whereas rf-linacs are designed as relativistic electron sources. The operation frequency of the beam pulse is, however, determined in this mode of operation by the round-trip time of the optical pulse in the optical resonator; that is, for typical laboratory dimension, this ranges from 10^{-8} to 10^{-7}s between electron pulses.

Moreover, the number of separated pulses must exceed a specific critical value, which depends directly on a FEL gain. This means that the macropulse length must be varied from several 10's of μ seconds to a few milisecond, when the operation is in a pulse mode.

The FEL gain is, on the other hand, linearly proportional to the beam brightness, and also proportional to the one-halfth power of the oscillation wave length. And the electron bunch lenght must be >> $\lambda_s N_w$, where N_w is the number of period in the undulator. Thus the effort during the phase 1 must be focussed on basic R&Ds for the FEL system.

The cost of the site preparation including the building construction usually exceeds that of the linac with other instrumentation. Therefore, the target room in the old building of the shut-down van de Graff accelerator could possibly be allotted. Right now the booster heavy-ion linac for the Tandem Accelerator is being assembled.

The room size is 14m x 25m wide, which is not enough for a higher energy linac for shorter wavelength oscillation. However, this can eliminate extra and less related works and therfore facilitate the FEL study. The above requirements and constraints lead us to the following choice;

1) a superconducting linac is preferable. (Use of new superconducting materials is hopefully expected after phase 2. Nb sputterd on a Cu cavity structure should be considered).
2) For a start, the laser wavelength can be set at 10.6μm (the same as the dominant line of CO_2 gas laser, and hence the optical instrumentation is easily available).

3. Specification of the Linac

The main parameters of a superconducting linac are tentatively listed below.

Beam Energy	40 MeV
Energy Resolution	< 0.1 %
Beam Peak Current	> 20 A
Beam Emittance	< 5π mm mrad
RF Frequency	1296 MHz
Bunch Width	10 ps
Bunch Repetition	12 MHz
Mode	CW or Long Macropulse

4. Design Consideration on the Injector System

The capability of delivering isolated pulse trains of electron bunches of high beam quality in a linac system is strongly governed by the properties of the injector.

As a first step a conventional injector currently used will be examined. It consists of a gridded gun driven by some average 100KV potential, a subharmonic buncher(SHB) which compresses current density of the cathode emission into intense bunch and then a bunching pre-accelerating section. The separation between the micropulses can be controlled by the grid driving pulse generator.

Preliminary parameters of this type of the injector are listed below for further consideration.

Type	Pierce
Cathode	dispenser cathode with a grid
Applied voltage	120 KV
Beam emittance	5 π mm mrad
Peak current	0.1 A (5 nsec)
Repetition rate of grid pulse	12 MHz
Width of grid pulse	5 nsec

Subharmonic Buncher

Type	a quarter-wave coaxial resonator
frequency	144 MHz
Acceptable phase angle	120° (2.3 ns)
Bunching phase angle	12° (0.23 ns)
Bunching length	720 mm
Average bunching time	4.5 ns

Pre-accelerating buncher

Frequency	1296 MHz
Input electron energy	120 KeV
Output	2.0 MeV
Energy resolution	1 %

In the above case, the resulting dilution of the transverse phase space and lower beam brightness will presumably become unacceptable for high performance FELs. An alternative approach without these drawbacks is the RF-gun, a type of rapid acceleration of beam by a cavity. An ideal RF-gun uses a high gradient field with a mode-locked laser driven photoemission cathode. With present day techniques it looks very elaborating to build such a photocathode and the associated drivers. Some laboratories prepare RF-guns with LaB_6 thermoionic cathodes for a main use and as a back-up.

Further examination of this configuration will be focussed on whether the control of the bunch separation is feasible or not. After that a simulation of the beam trajectories will follow and the availability of the hardware will be checked.