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100-200 μm 대역 원적외선 자유전자레이저

Far-Infrared Free Electron Laser Tunable in the Wavelength Range of 100-200 μm

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In free electron lasers (FELs), a beam of relativistic electrons pass through an undulator (a structure generating periodic transverse magnetic field) and produce coherent rariation. One of the advantages of FEL is its tunability of wavelength over much wider range than those of conventional lasers. By changing either the beam energy or the field strength we can change the wavelength easily and rapidly over a wide range. The other advantage is that it can generate wavelengths that are not obtainable by using conventional lasers. Especially in the far-infrared (FIR) region of wavelength, the FEL is a very promising tool for scientific research because, in this region of wavelength, the non-laser sources are weak and the use of conventional laser sources is very limited [1,2].

The wavelength of the FIR FEL being developed at KAERI is continuously tunable over the range from 100 μm to 200 μm. Fig. 1 shows a schematic of te FEL. It is composed of a microtron : which is a compact electron accelerator, an undulator, a beamline : which transport the electron beam from the microtron to the undulator, and an optical cavity. The pulse duration of a micropulse is 15 ps and the peak power is about 1 kW. Fig. 1 shows a schematic diagram of the FIR FEL system. The parameters of the system are listed in Table 1. The wide-range continuous tunability, the short pulse duration and the high peak-power make the FEL a promising source of radiation for scientific researches. The use of a compact microtron as a source of relativistic electron beam makes the system compact. The overall dimension of the system is small enough such that it can be installed inside a laboratory.

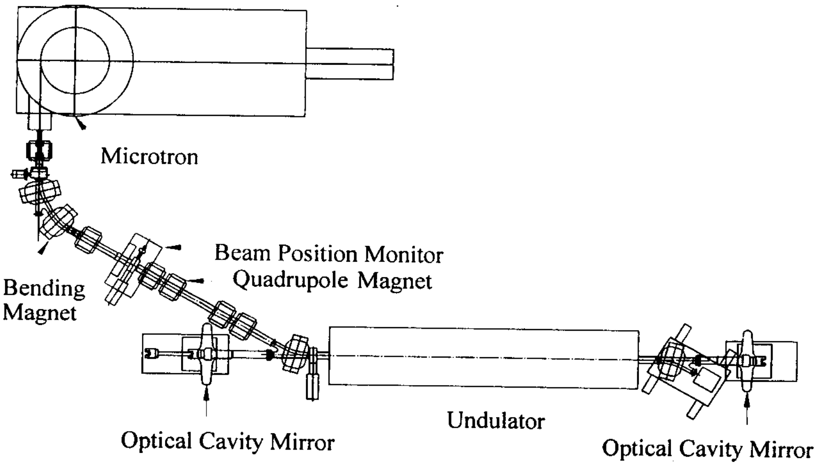

Fig.1 Schematic of the KAERI far-infrared free electron laser

Coarse tuning of wavelength is done by changing the energy (E) of the electron beam, and fine tuning is done by changing the magnetic field strength (B_u) of the undulator. uning

Table 1. Parameters of the FIR FEL system

Electron Beam	Wavelength	100 - 200 μm
	Micropulse Duration	15 ps
	Micropulse Repetition Rate	2.8 GHz
	Micropulse Peak Power	1 kW
	Macropulse Duration	5 μs
	Macropulse Repetition Rate	1 - 10 Hz
Electron Beam	Energy (E)	6.0 - 7.5 MeV
	Energy Spread	0.3 %
Undulator	Period (L_u)	25 mm
	Number of Periods	80
	Field Strength (B_u)	5.5 - 6.5 kG

of the wavelength is done by changing either the energy of the electron beam or the field strength of the undulator. The wavelength of the FEL is determined by the equations :

$$\lambda = \frac{L_u}{2\gamma^2}\,(1+K^2/2), \quad \gamma = 1+\frac{E\,[MeV]}{0.511}, \quad K = 0.95\, B_u\,[T]\; L_u\,[cm],$$

where L_u and B_u are the period and the field strength of the undulator, respectively, and E is the energy of the electron beam.

A new type of has been developed for the FIR FEL, which is very easy to fabricate, operate, and maintain. An alternating magnetic field is induced by the electric coils wound around an assembly of alternating magnetic poles made of iron. The magnetic field can be changed very quickly such that the wavelength of the FEL can be changed in a very short time. The error in the spatial distribution of undulator field should be less than 0.1 %.

The optical cavity is composed of a waveguide vacuum channel, two mirrors, and a vacuum window. The cross-sectional dimension of the 2-m-long channel is 20 mm x 2 mm. The cavity mode is a combination of free-space mode with confocal geometry in horizontal direction, and waveguide mode in vertical direction. The material of the mirror is glass coated with gold. Output coupling of the radiation is done by using a hole located at the center of the mirror.

Many applications of the FIR FEL in chemistry, surface science, solid-state physics, biophysics, plasma diagnostics, etc. are expected [6]. The photon energy of the FIR FEL radiation corresponds to the rotational transition energy of large molecules. The Fourier-transform-limited linewidth of the FEL is several cm^{1}. The linewidth is small enough for the study of photochemical processing. For bulk, homogeneous materials the photon energies of the FIR FEL radiation overlap essentially completely the principal excitations in condensed matters : phonons, plasmons, magnons, and inter-band transitions. The population relaxation time of the heavy-hole light-hole transition in bulk semiconductors (such as p-Ge) is several tens of ps. The picosecond pulses of the FEL would allow the study of energy transfer processes at surfaces.

[1] "Free Electron Lasers and Other Advanced Sources of Light", National Research Council, National Academy Press, Washington DC. (1994)

[2] The World-Wide Web Virtual Library : Free Electron Laser (http://sbfel3.ucsb.eud/www/vl_fel.html)