Investigations of Radiation Production from an RF Undulator

A proposal to the Brookhaven Accelerator Test Facility

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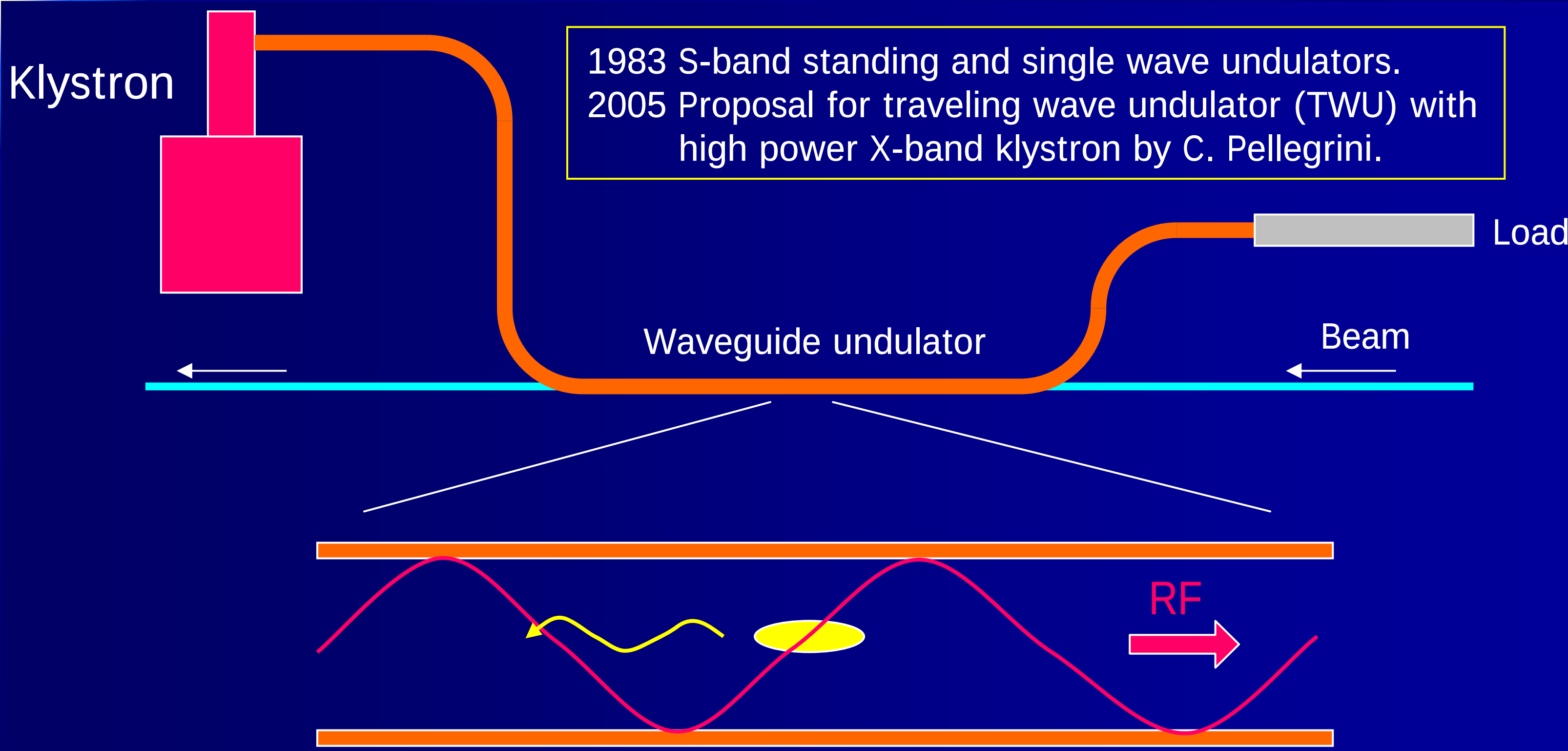
Outline

- What is RF undulator?
- Estimate the property of the RF undulator for the test.
- Deflection in the transition region.
- Expected diagnostics.
- “Boundary conditions” for the investigation of RF undulator at ATF.
- Summary.

RF undulator

1983 S-band standing and single wave undulators.
2005 Proposal for traveling wave undulator (TWU) with high power X-band klystron by C. Pellegrini.



- Alternating field made in a waveguide by feeding high power RF acts as an undulator, instead of a set of alternating magnets.

- The development of a 100 MW X-band klystron enables TWU experiments.

Waveguide Undulator

Advantages

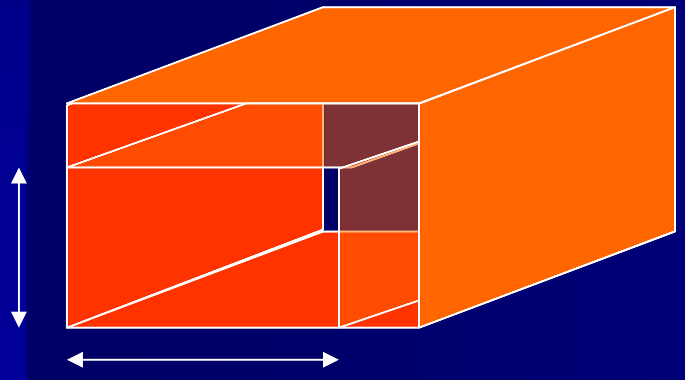
- A simple, straightforward to manufacture, waveguide geometry.
- Large apertures with short undulator wavelengths.
- Large *K* values with existing X-band sources.
- Circular polarization may be implemented.
- The field uniformity is guaranteed within the precision of machining.
- The cost per meter of the undulator may be lessened.

Issues

- Reliability of dealing with high powers in the TWU waveguide.
- Management of secular decay in the field due to attenuation.
- Potential for large deflections at the TWU entrance.
- Inherent transverse defocusing.
- The challenge of diagnosing and controlling the beam inside of very high power wave-guide environment.

Undulator parameters

RF frequency	11.424 GHz	
RF power	100 MW	
Waveguide	WR90 (22.86 x 10.16 mm^2)	15.77 x 7.01 mm^2
Mode	TE_{10}	
Critical Frequency	6.56 GHz	9.51 GHz
Field Attenuation	1.1 %/m	3.0 %/m
Equivalent undulator period	14.4 mm	16.9 mm
Equivalent magnetic field	0.17 T	0.26 T
K	0.23	0.41



Scaled in area down by 2.1 in order to obtain higher K.

Longer period

Higher beam energy

Higher attenuation

Tapered waveguide (if required)

Estimation for FEL Experiments

Waveguide	WR90 (22.86 x 10.16 mm^2)	15.77 x 7.01 mm^2
Radiation wavelength	532 nm	
Beam energy	60.3 MeV	66.9 MeV
I	300 A	
β	0.5 m	
ε	2 mm.mrad	
FEL parameter (1D)	(0.0064)	(0.0096)
Gain Length (1D)	(0.32 m)	(0.25 m)
Rayleigh Length	0.20 m	0.18 m

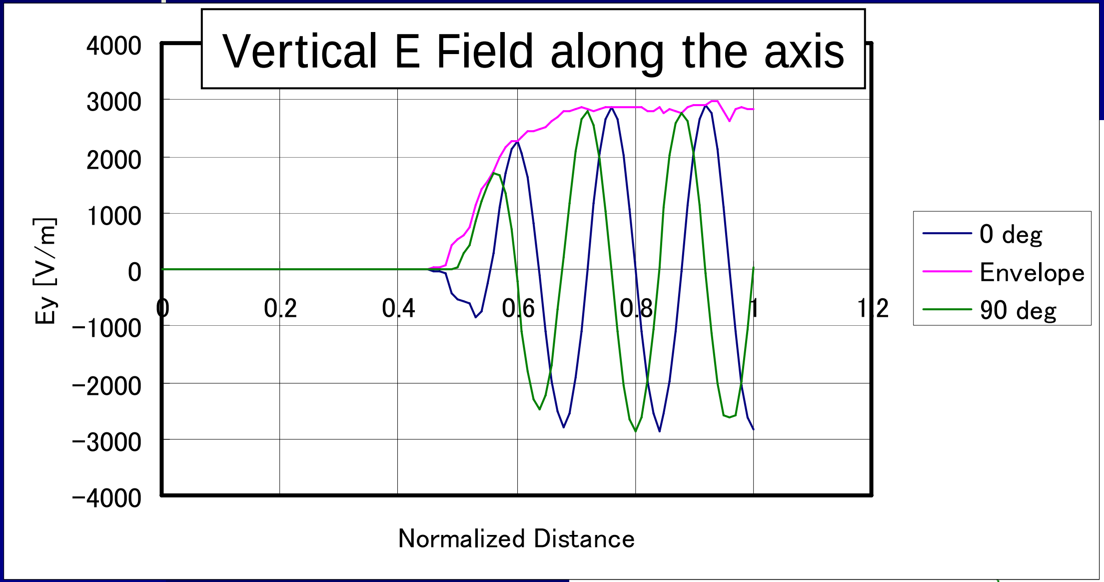
Required numerical analysis for precise gains since $L_R < L_G$.

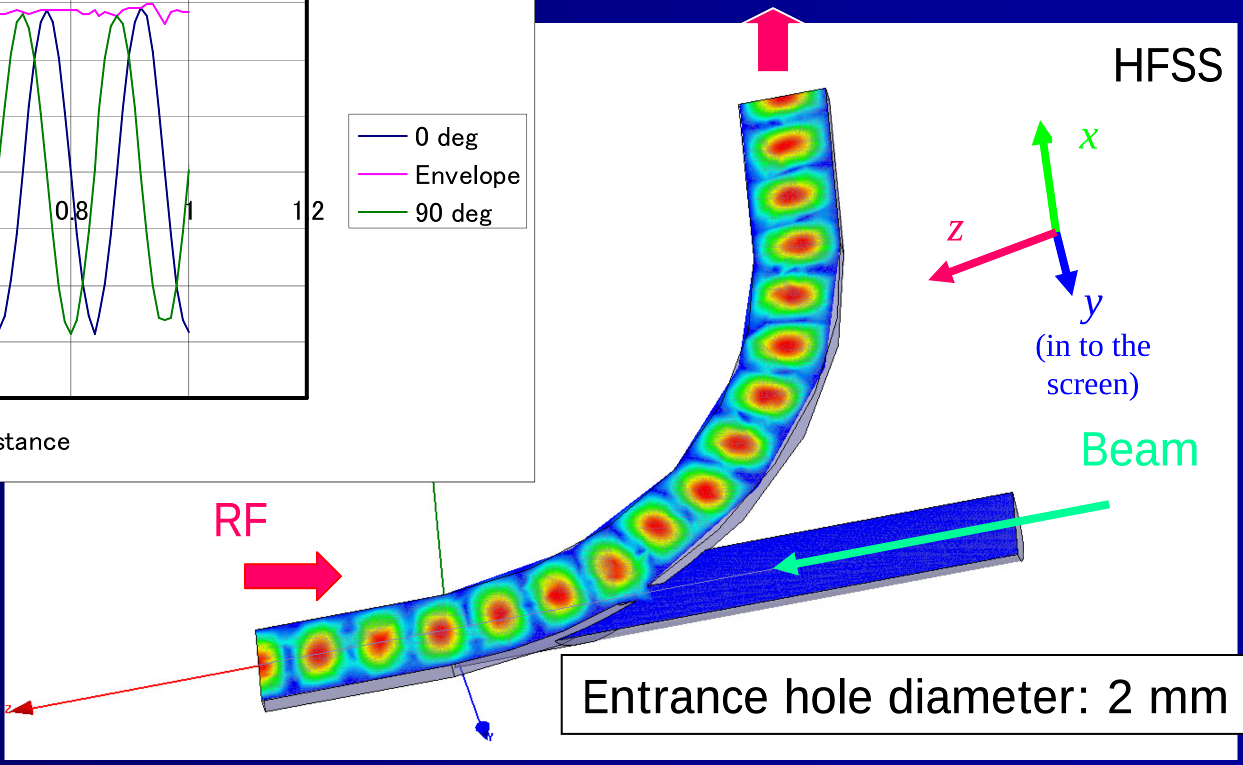
Seeded FEL

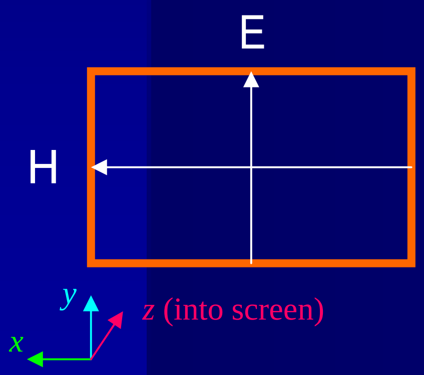
Gain of 2.3 for the smaller waveguide with 1 m interaction (GENESIS)

→ Observable

Potential for deflection in the transition region at the entrance of the waveguide





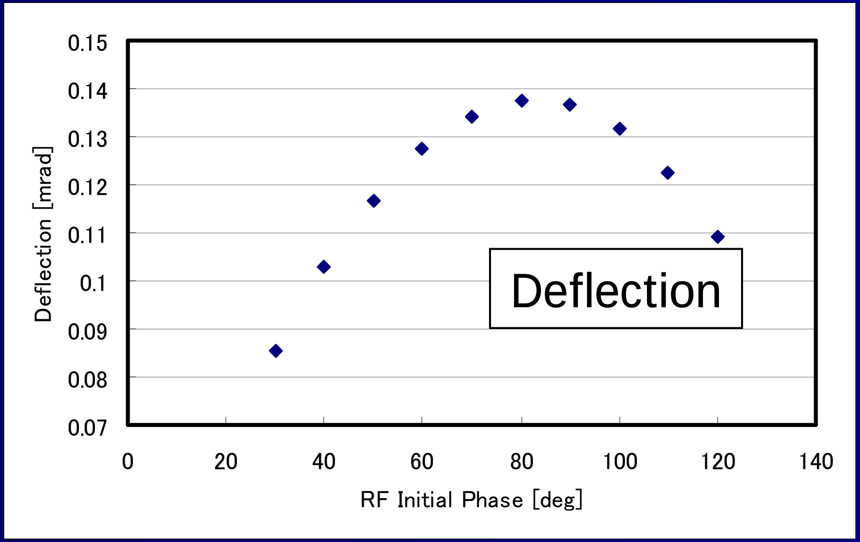


Field direction in the waveguide

Inhomogeneous field can cause deflection.

1D simulation for estimation of deflection

- The beam energy is 70 MeV.
- The input RF power is 50 MW. → 0.14 mrad at the maximum.
- WR90



Smaller deflection with proper phases

- 0.23 mrad for the beam energy of 60 MeV and the input RF power of 100 MW.

Klystron should be operated at the RF phase which yields the minimum deflection.

Diagnostics

Beam diagnostics

- Deflection in the transition region
- Defocusing effect

CCD camera and screen
(Ce:YAG screens used on previous VISA and ATF compressor experiment)

FEL diagnostics

- Spontaneous emission
- Gain for seeded FEL at 532 nm.

We can use instruments of VISA experiment, while some of them are required to be replaced for 532 nm. (VISA is run at 800 – 1080 nm)

These diagnostics are almost in hand.

The "Boundary Conditions" for the Investigations

RF

- 100 MW of RF power at 11.424 GHz. → Specifications of the SLAC Klystron at ATF.
- linearly polarized waves.
- Flat top waveform. → Will be obtained in normal operation.

Beam

- A 60 MeV, 300 A peak e-beam with 2 mm-mrad emittance. → Demonstrated at UCLA/ATF compressor experiment.

Physical Space

- 1 m of free space for installation. → The downstream straight-through beamline (H-line).

Radiation

- Fundamental radiation wavelength foreseen at 532 nm. → Can be obtained provided the proper beam energy and waveguide.

A set of the first, proof-of-principle experiments on the TWU experiment seems to be able to be performed at ATF.

Summary

We proposed for an X-band RF undulator experiment.

RF undulator

- WR90 or smaller waveguide.
- The input power is 100 MW at 11.424 GHz.
- K value is 0.23 or 0.41.

Beam and beamline

- A 60 or 67 MeV, 300 A peak e-beam with 2 mm-mrad emittance.
- 1m of the space for the installation in the beamline is expected.

Diagnostics

- Deflection (0.23 mrad at the maximum) and defocusing effect.
- Spontaneous emission and gain (2.3 by GENESIS) of seeded FEL at 532 nm.