Dielectric lined waveguide based THz radiator study for SwissFEL

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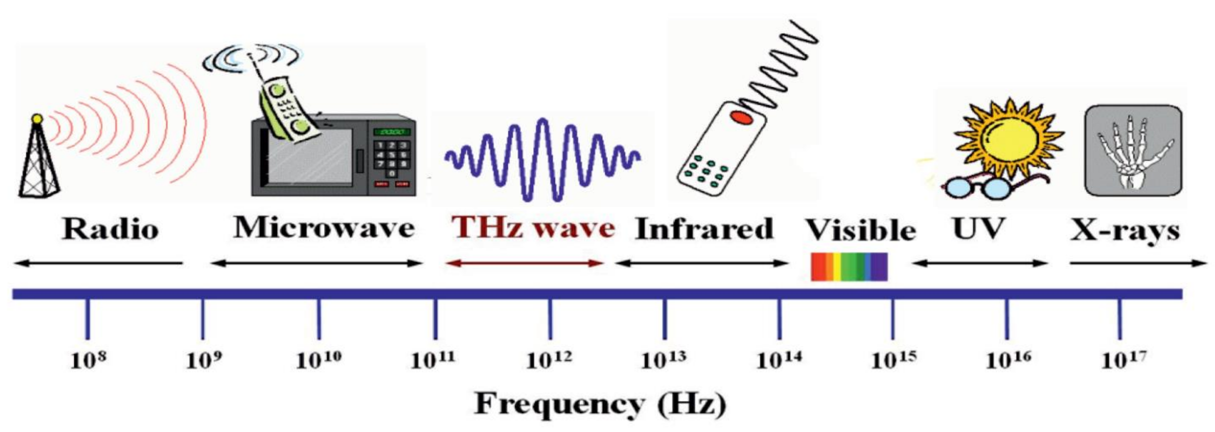
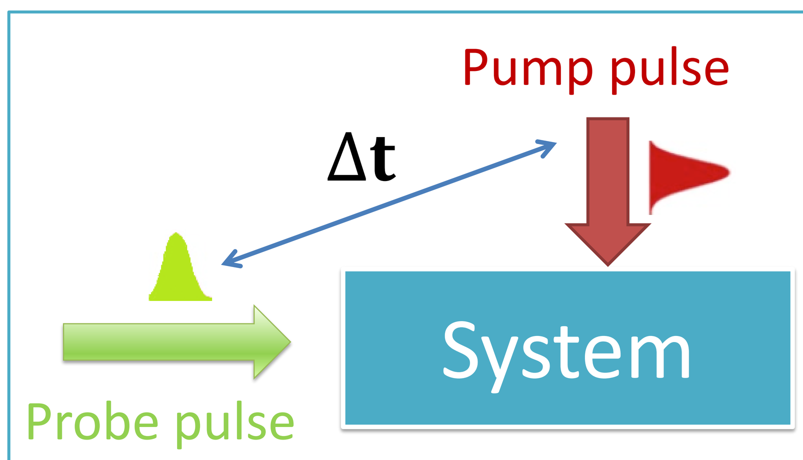
1. Abstract

We investigate the possibility of exploiting the dielectric lined waveguide as a means to generate intensive, powerful, narrowband terahertz pulses in the range of 1-20 THz. By sending a relativistic electron bunch through the waveguide, an electromagnetic field can be excited which is trailing the excitation electron beam. A part of the kinetic energy of the beam is converted into THz radiation with a properly designed dielectric lined waveguide. By guiding the radiation out of the waveguide, it can be used for various experiments. We present the numerical study of these waveguides, in terms of mode structure, energy, pulse length etc. The THz and the X-ray pulses at SwissFEL can form a powerful pump-probe experimental scheme.

2. Motivation

The non-ionizing interaction between THz pulses and the material.

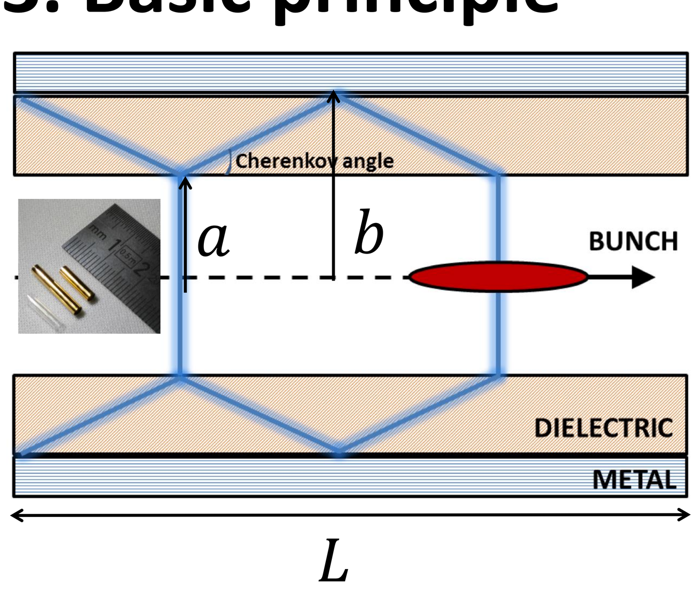




1.Pump pulse is from external source (THz source).

2.Probe pulse with high power and tens fs duration is from the accelerator-based X-ray.

3. Basic principle



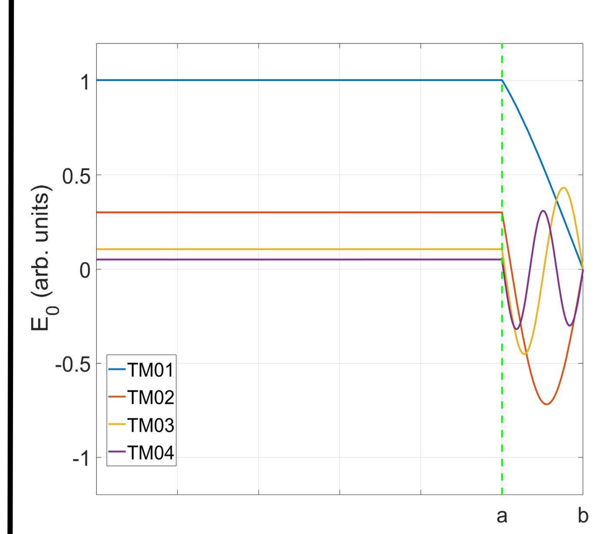
- Electric field polarizes the dielectric material
- Polarized material radiates at a characteristic angle
- The radiation is reflected back and forth to form the mode structure
- The field distribution is tunable with the beam and DLW parameters.

- The loss of beam energy (pulse energy) per meter $\propto \frac{q^2}{a^2}$
- The pulse duration (inverse of bandwidth) $\propto L\left(\frac{1}{V_g}-\frac{1}{c}\right)$
- The pulse center frequency is jointly determined by the inner and outer radius (a,b) and the dielectric material.

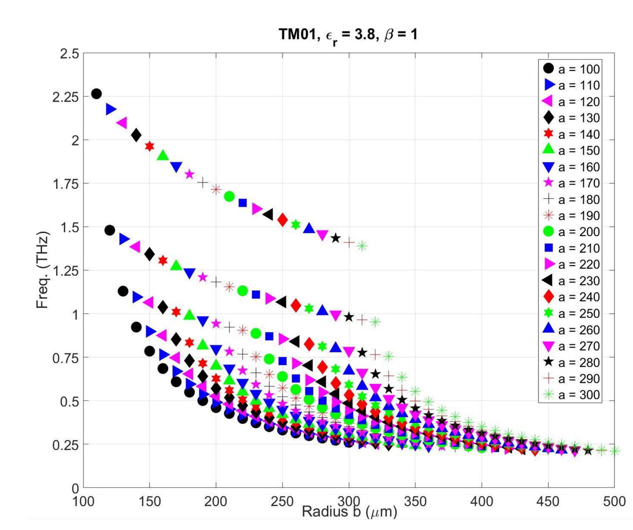
4. Objectives

- Pulses of 1-3 THz from TM_{01} and 3-20 THz from its harmonics
- Less than 10% bandwidth (preferably 5%)
- > 100 μJ per pulse

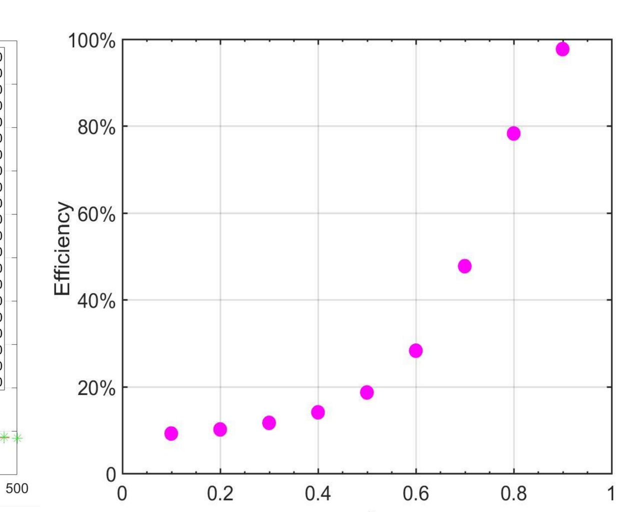
5. Numerical investigations



Transverse profile of the longitudinal field strength of the TM mode



TM01 mode frequency versus radius b at different a

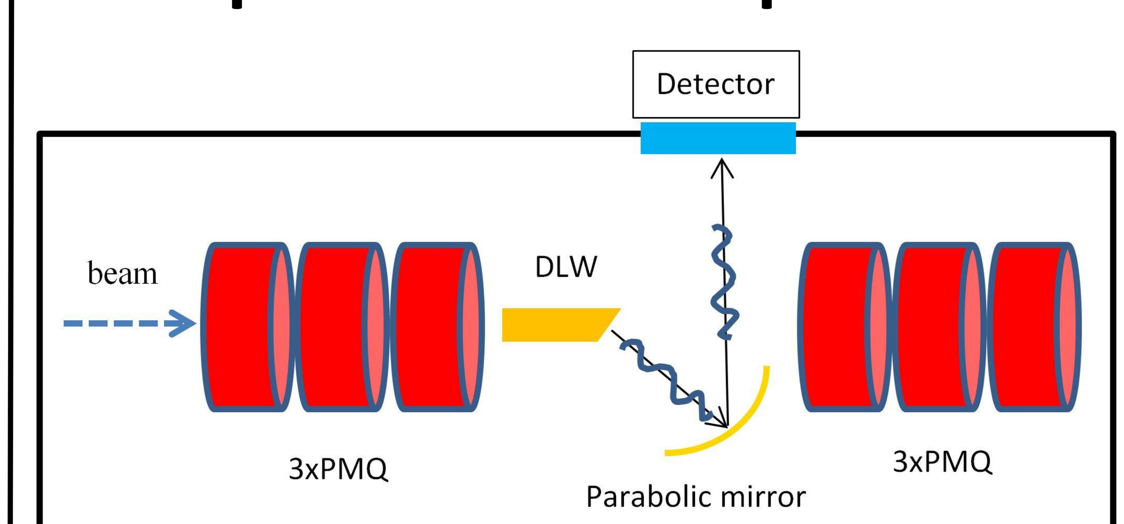


Radiation extraction efficiency

THz pulse parameter estimation for a point charge of 1 pC

TM_{0n} n	Freq. (THz)	Vg (c)	E (μJ)	T_{pulse} (ps)	E0 (MV/m)	BW (%)
1	1.48	0.53	0.0113	30	2.26	2.2
2	5.06	0.75	0.0034	11	0.68	1.8
3	9.29	0.78	0.0012	9.6	0.24	1.1
4	13.66	0.78	0.0006	9.2	0.11	0.8
5	18.09	0.79	0.0003	9.2	0.07	0.6

6. Experimental setup

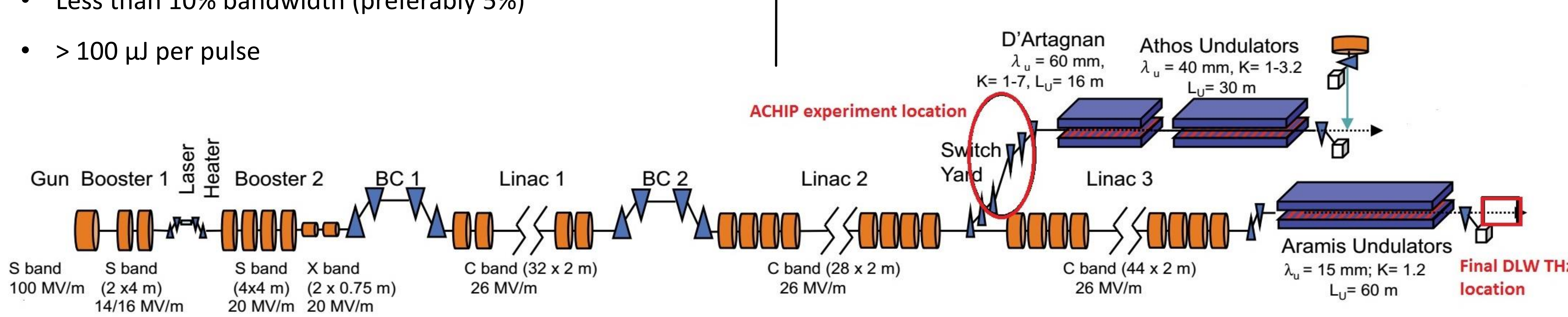


- Setup will be situated in the ACHIP chamber
- Three permanent magnets used for focusing the e beam
- THz radiation is guided out of DLW and transported to detector for characterization

7. Conclusion and outlook

We have overviewed the project and investigated the THz generation based on a dielectric lined waveguides numerically. A possible experimental setup is also described for the upcoming experiments.

The DLWs will be processed and tested in the lab and SwissFEL in the near future.



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