Multi-foil THz radiation (reporting works by N. Vinokurov et al. in KAERI, Korea)

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October 12, 2015

Motivation

Motivation:
In 2013 N. Vinokurov and Y. Jeong proposed a method that allows to increase the intensity of THz radiation from a metal foil by stacking many thin foils into a conically shaped assembly. At FEL 2015 they reported an experiment that demonstrated an order of magnitude increase in the radiation energy.

The multi-foil radiator has a promise to increase the radiated energy by more than order of magnitude.

Original publications

PRL **110,** 064805 (2013) PHYSICAL REVIEW LETTERS week ending 8 FEBRUARY 2013

Generating High-Power Short Terahertz Electromagnetic Pulses with a Multifoil Radiator

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(Received 13 October 2012; published 7 February 2013)

Proceedings of FEL2015, Daejeon, Korea - Pre-Release Snapshot 30-Sep-2015 00:00 WEP082

HIGH-POWER ULTRASHORT TERAHERTZ PULSES GENERATED BY A MULTI-FOIL RADIATOR WITH LASER-ACCELERATED ELECTRON PULSES

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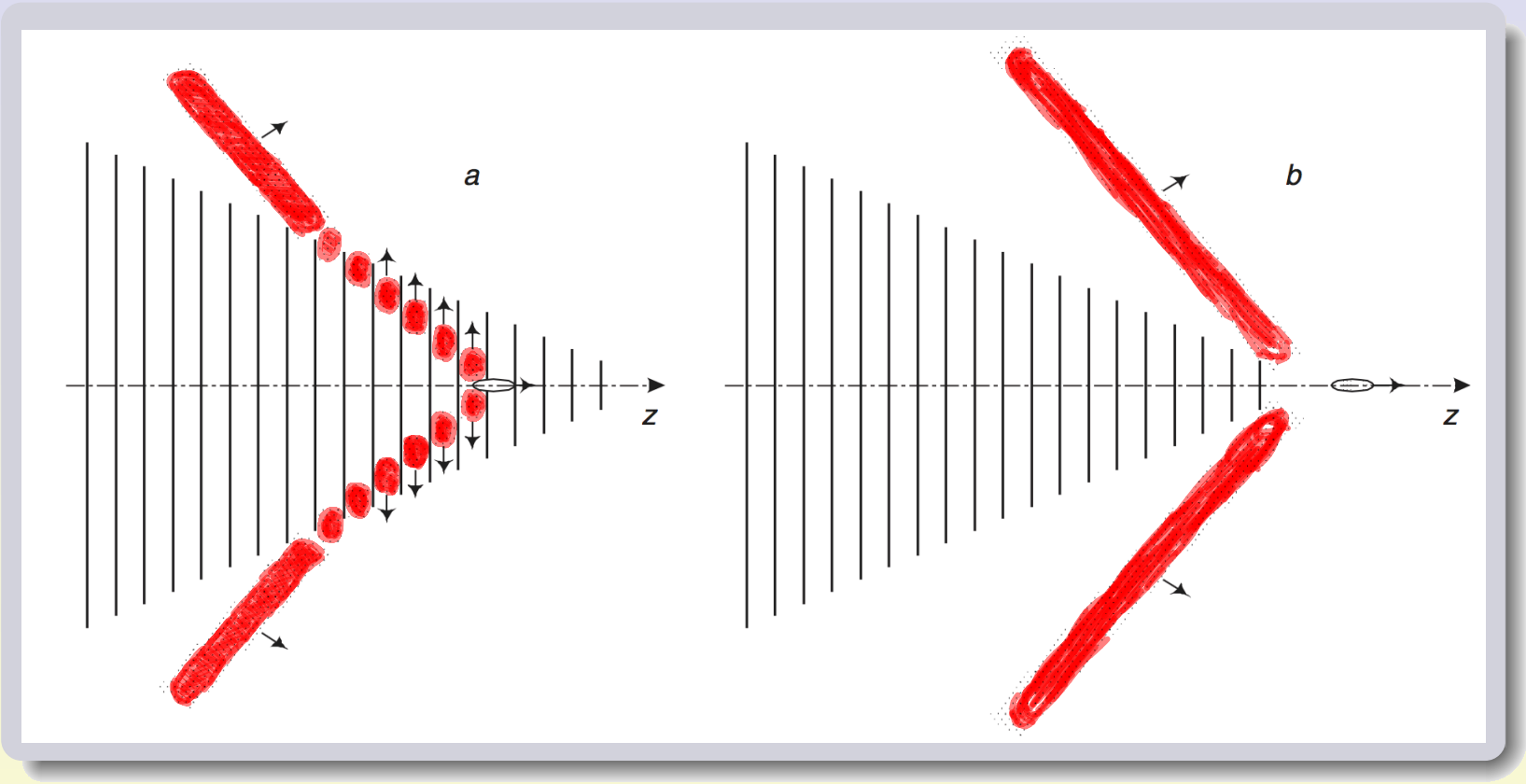
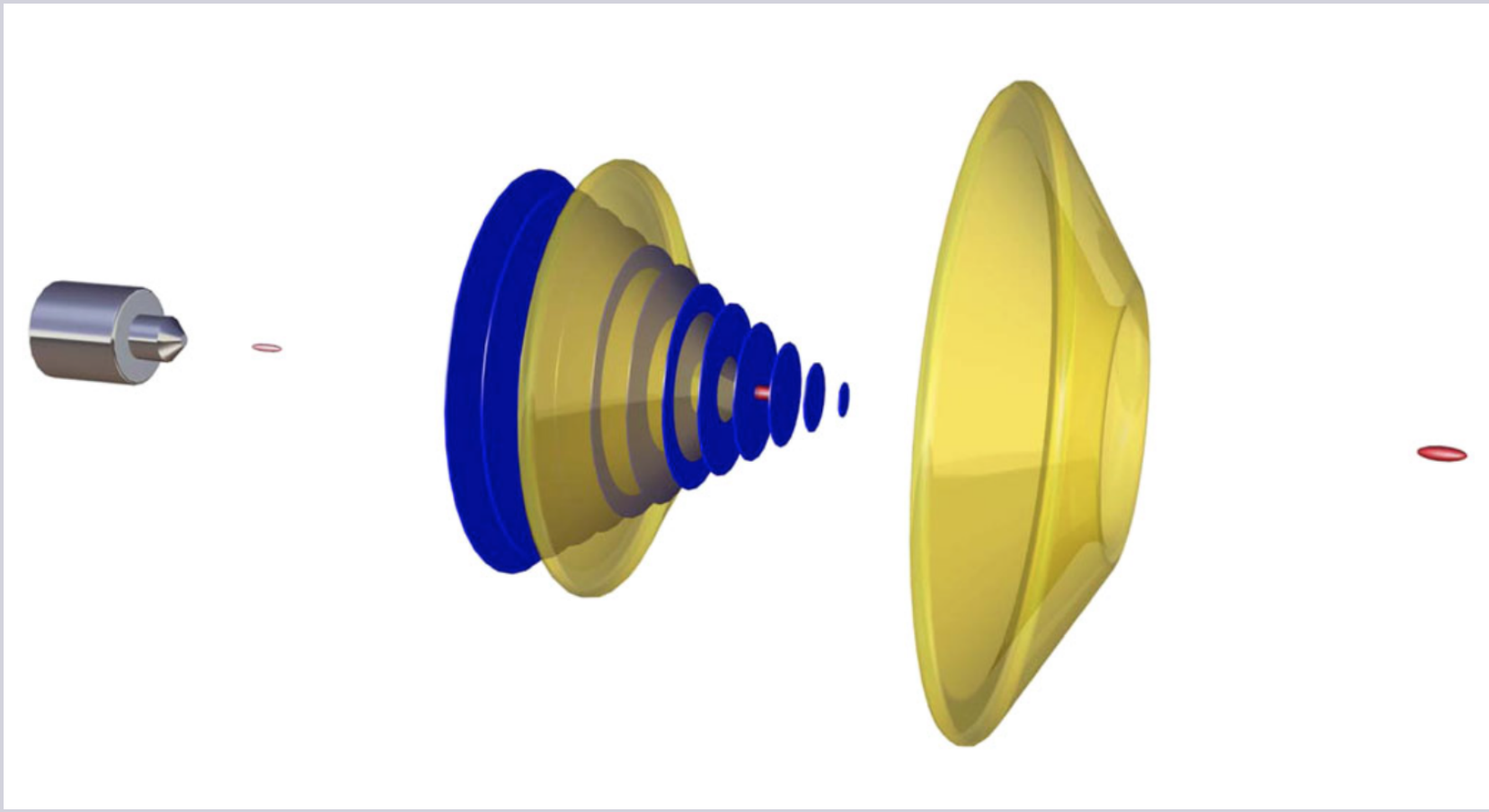
Setup

Round thin foils with diminishing radii are stacked and a short electron bunch passes through the foils on axis. The gaps between the foils can be filled with a dielectric.



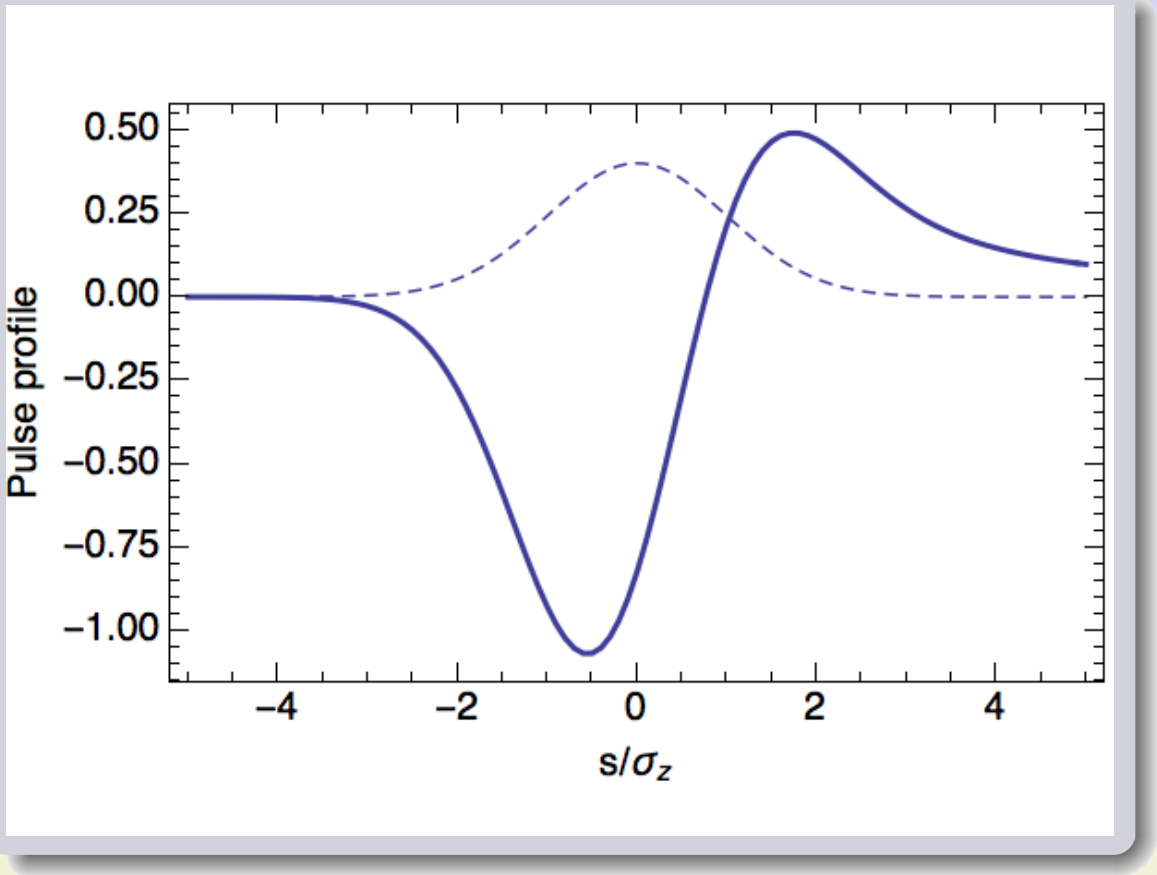
3D picture of the conical wave

Radiator and EM pulse.



Radiation pulse is short and intense

The radiation pulse is short, on the order of the bunch length.

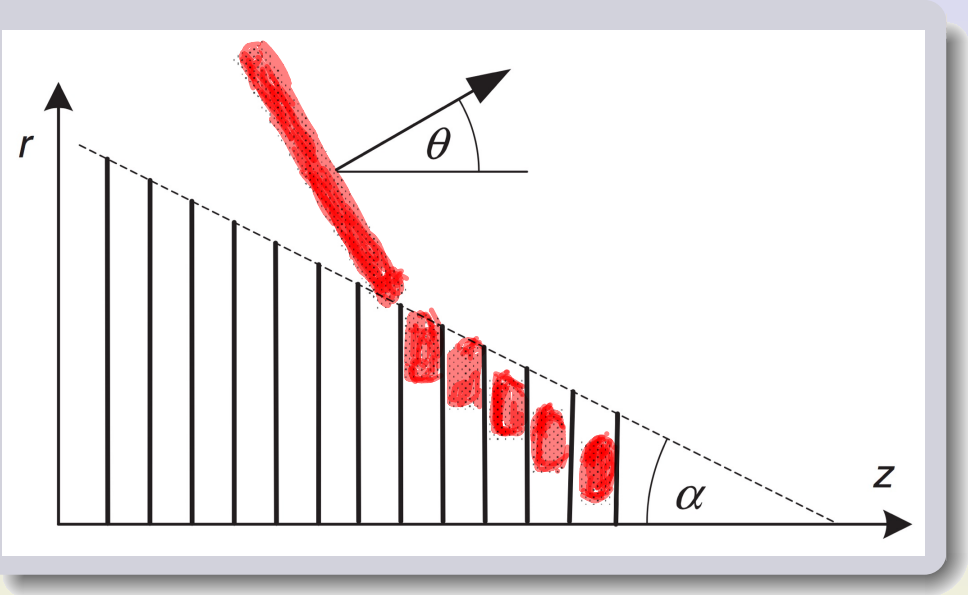


The radiated energy compared with the energy from one foil

$$\frac{W_{\mathrm{stack}}}{W_1} \approx \mathrm{N}_{\mathrm{foil}} \frac{\sqrt{\pi}}{2\ln(\mathrm{R}/\sigma_\perp)}$$

Optimal cone angle

When the wave exits the stack, it propagates at some angle θ that depends on α. A part of it is reflected back from the boundary. There is an the optimal angle θ with no reflection.



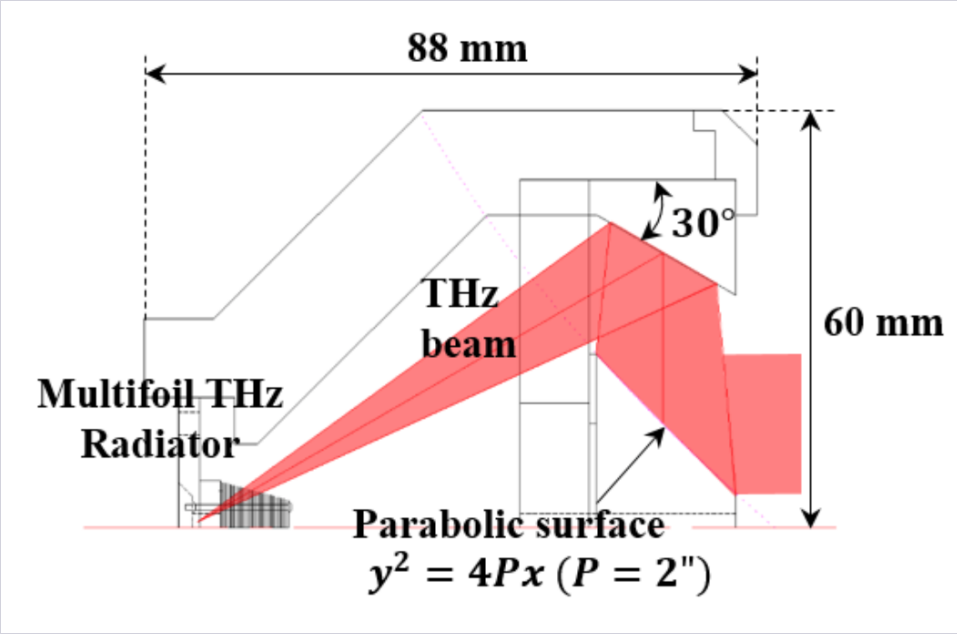
$$\alpha_0 = \arctan\frac{1}{2} = 26.6^\circ$$

$$\theta_0 = 36.9^\circ$$

The foils can be considered as a anisotropic metamaterial with conductivities $\sigma_{\parallel} = 0$ and $\sigma_{\perp} = \infty$. The radiation is the Cherenkov radiation in the media. The angle α_0 is the Brewster angle.

Experiment

The experiment was performed with 80-100 MeV electron beam with $\sigma_t \approx 30$ fs, obtained from laser-plasma acceleration. The multi-foil consisted of 35 Ti sheets of 50 μm thickness, in air.

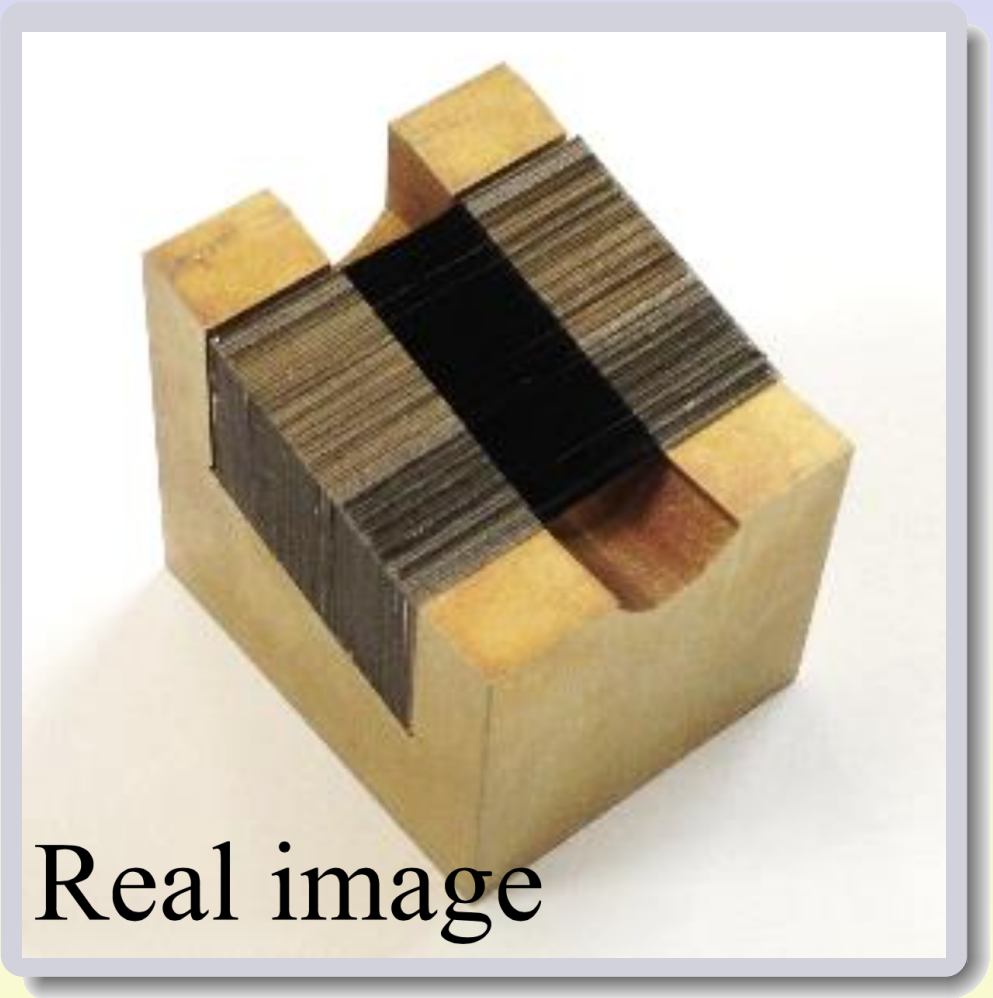


A special collimator collected and directed the radiation.
The tolerances on the gaps between the foils are loose (should be smaller than the radiation wavelength).

Collimator

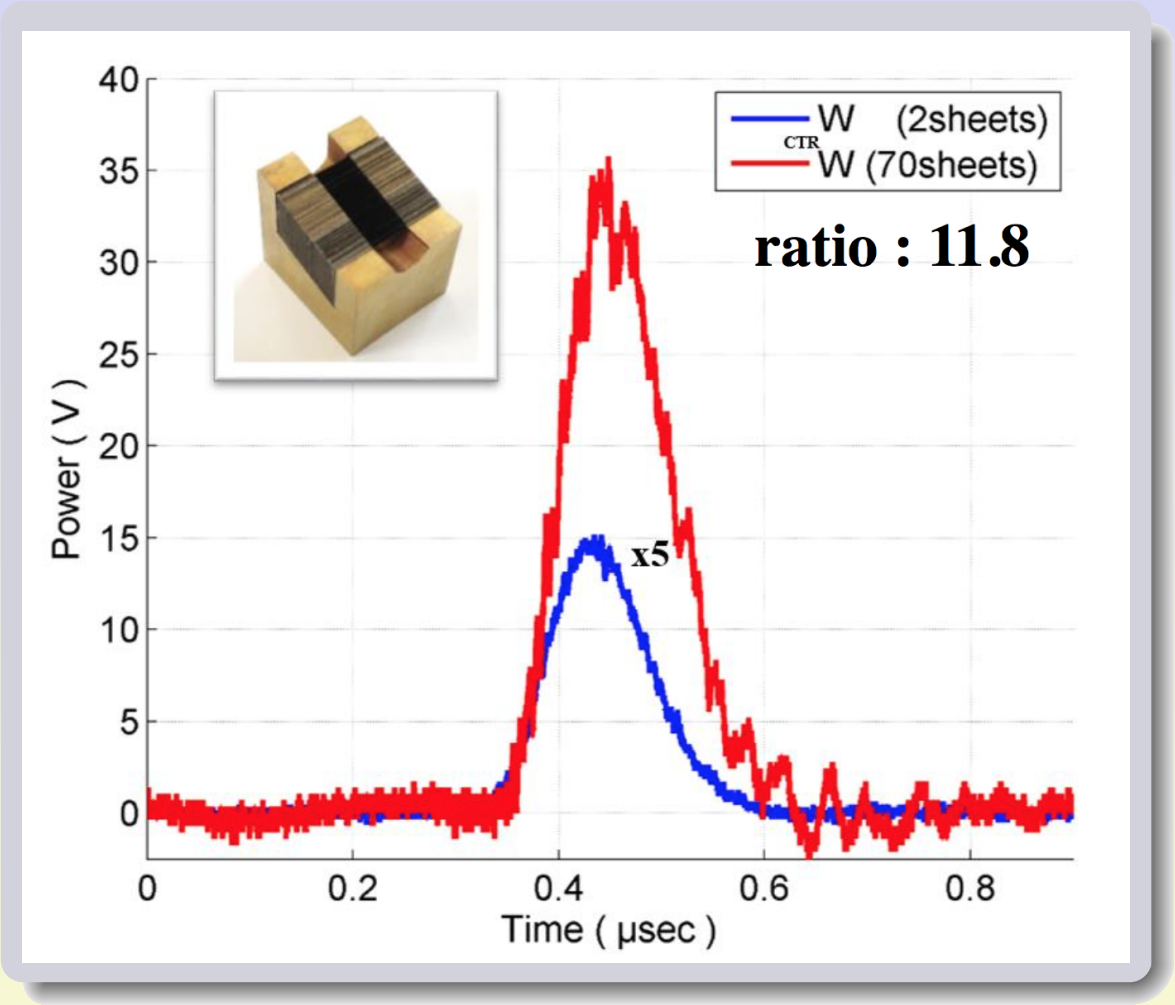
Another type of radiator

Linear polarization type of radiator: 70 Ti foils, 5 μm thickness, 300 μm gap.



Experimental results

Comparison of the signal from a cooled bolometer for 2 foils and 70 foils.



Theoretical expectation: 27.23.

Conclusions

- The multi-foil radiator has a promise to increase the radiated energy by more than order of magnitude in comparison with a single foil. With high charge and short bunch length of the FACET-II beam this could result in record THz pulse energy.
- Theory predicts the the scaling $W \propto \mathrm{N}_{\mathrm{foils}}$. The pulse duration is of the order of the bunch length.
- Special effort is needed to collect and transport the radiation pulse.