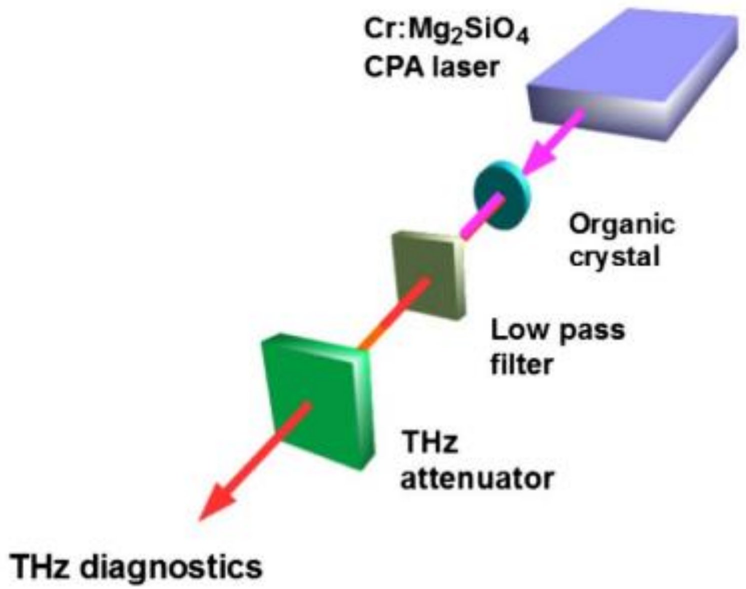
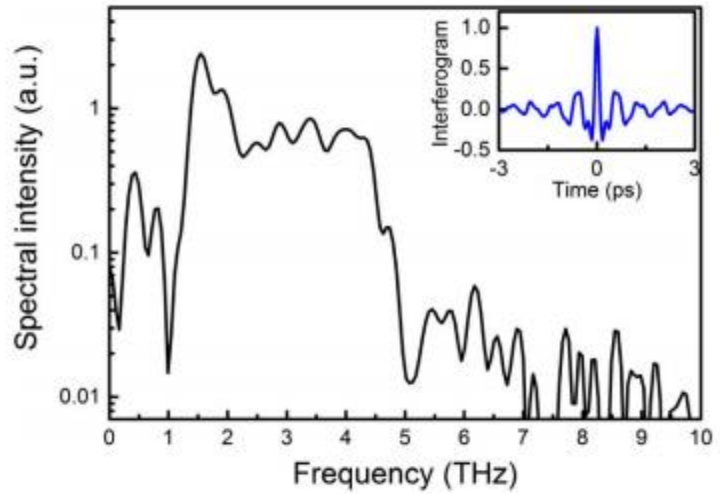
Multi-Cell Accelerating Structure Driven by a Lens-Focused Picosecond THz Pulse

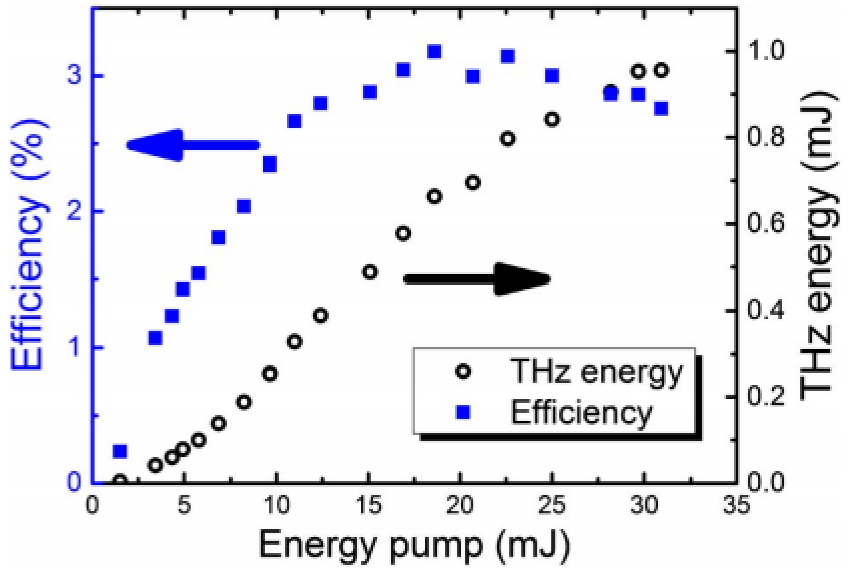
Sergey P. Antipov, Sergey Vladimirovich Kuzikov (Euclid TechLabs, LLC, Solon, Ohio), Alexandr A. Vikharev (IAP/RAS, Nizhny Novgorod)

Recently, gradients on the order of 1 GV/m level have been obtained in a form of a single cycle (~1 ps) THz pulses produced by conversion of a high peak power laser radiation in nonlinear crystals (~1 mJ, 1 ps, up to 3% conversion efficiency) [1]. Such high intensity radiation can be utilized for charged particle acceleration. However, these pulses are short in time (~1ps) and broadband, therefore a new accelerating structure type is required. In this paper we propose a novel structure based on focusing of THz radiation in accelerating cell and stacking such cells to achieve a long-range interaction required for an efficient acceleration process. We present an example in which a 100 microJoule THz pulse produces a 600 keV energy gain in 5 mm long 10 cell accelerating structure for an ultra-relativistic electron. This design can be readily extended to non-relativistic particles. Such structure had been laser microfabricated and appropriate dimensions were achieved.

Laser – driven THz pulse production







Generation of 0.9-mJ THz pulses in DSTMS pumped by a $Cr:Mg_2SiO_4$ laser

C. Vicario,[1] A. V. Ovchinnikov,[2] S. I. Ashitkov,[2] M. B. Agranat,[2] V. E. Fortov,[2] and C. P. Hauri[1,3,*]

[1]*Paul Scherrer Institute, SwissFEL, 5232 Villigen PSI, Switzerland*

[2]*Joint Institute for High Temperatures of RAS Izhorskaya st. 13 Bd. 2, Moscow 125412, Russia*

[3]*Ecole Polytechnique Federale de Lausanne, 1015 Lausanne, Switzerland*

**Corresponding author: christoph.hauri@psi.ch*

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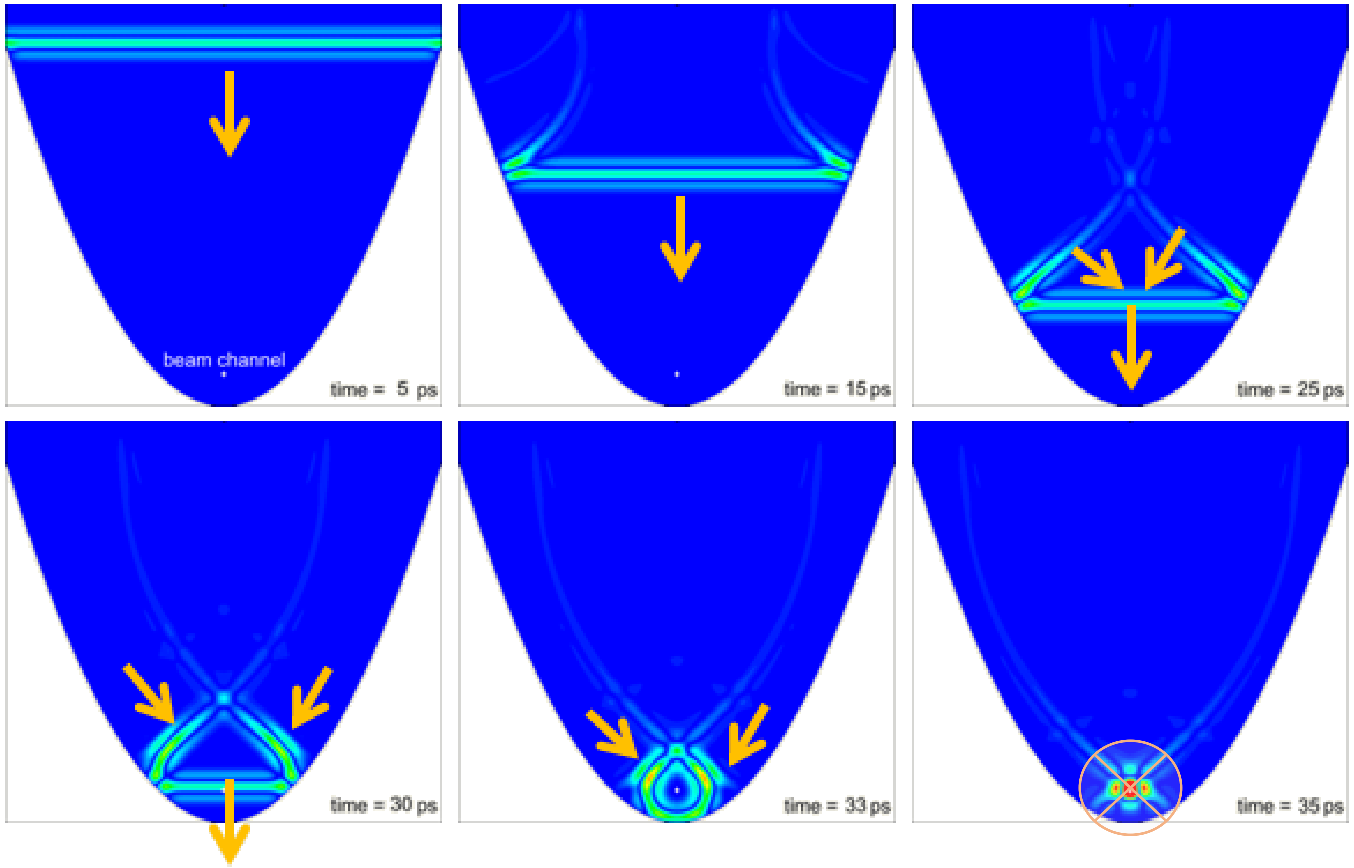
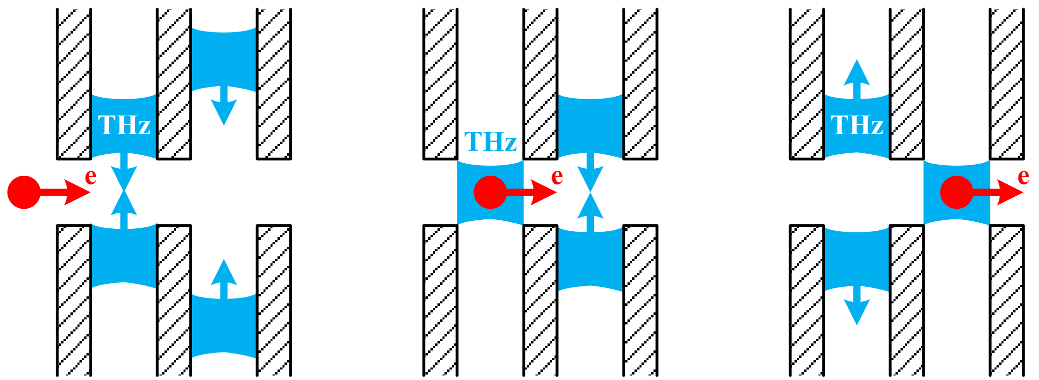
focusing optics and wavefront optimization [28]. Under these conditions, field strength of 80 MV/cm and 27 Tesla, respectively, is feasible, which surpasses any laser-based and accelerator based THz sources by about an order of magnitude in the frequency range of 0.1–5 THz.

Focusing by parabolic mirror, time-lapse

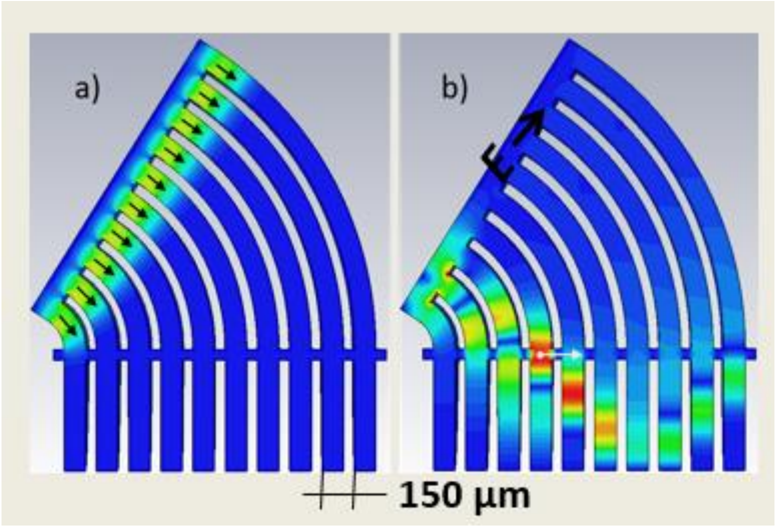


Timing THz pulses and e-beam

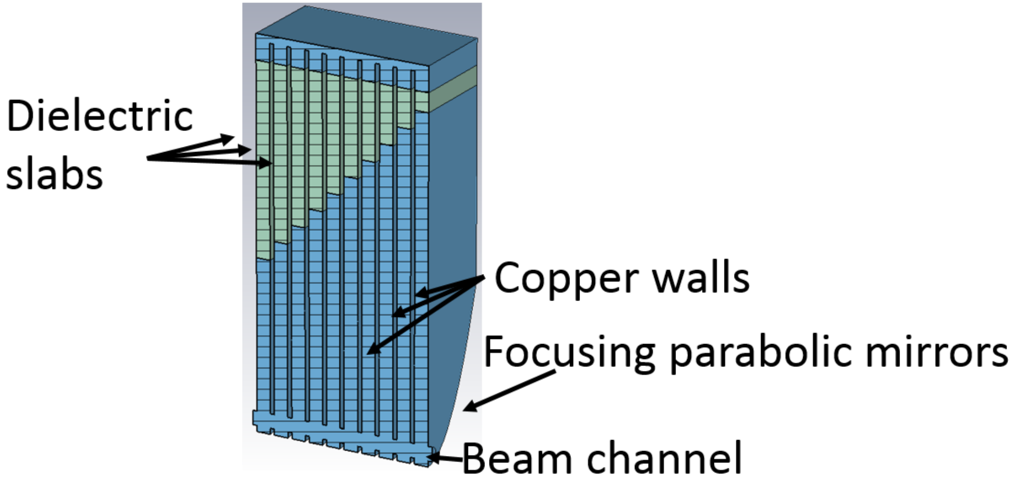
Each channel has to have delay to match electron speed

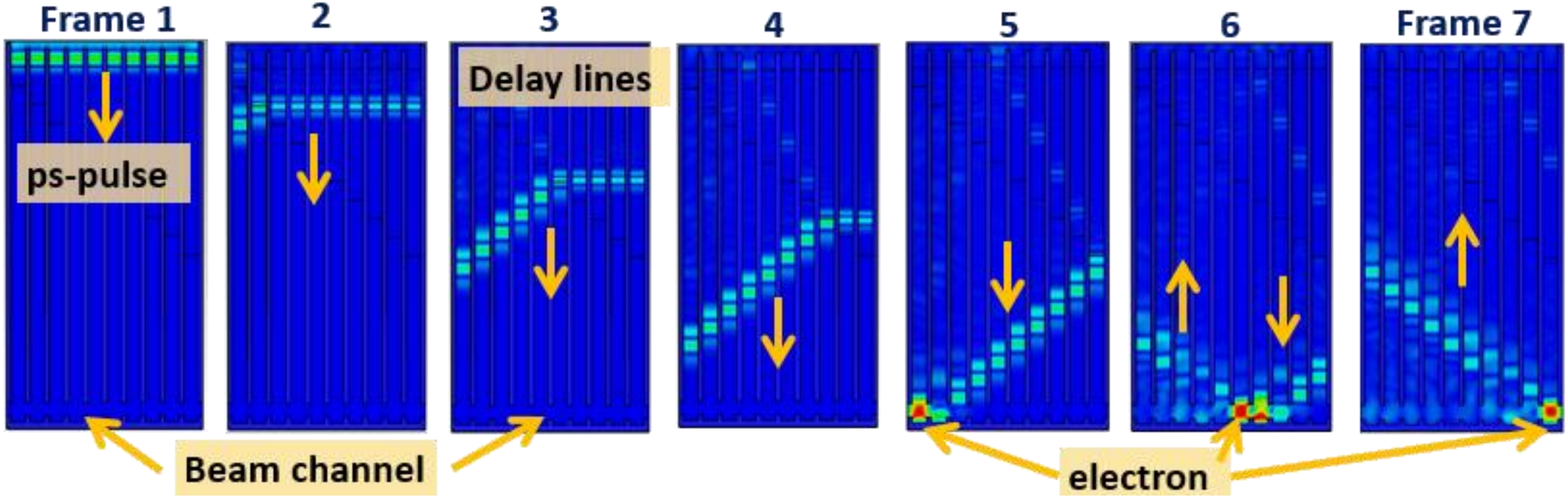


Timing by optical path delay: difficult to fabricate

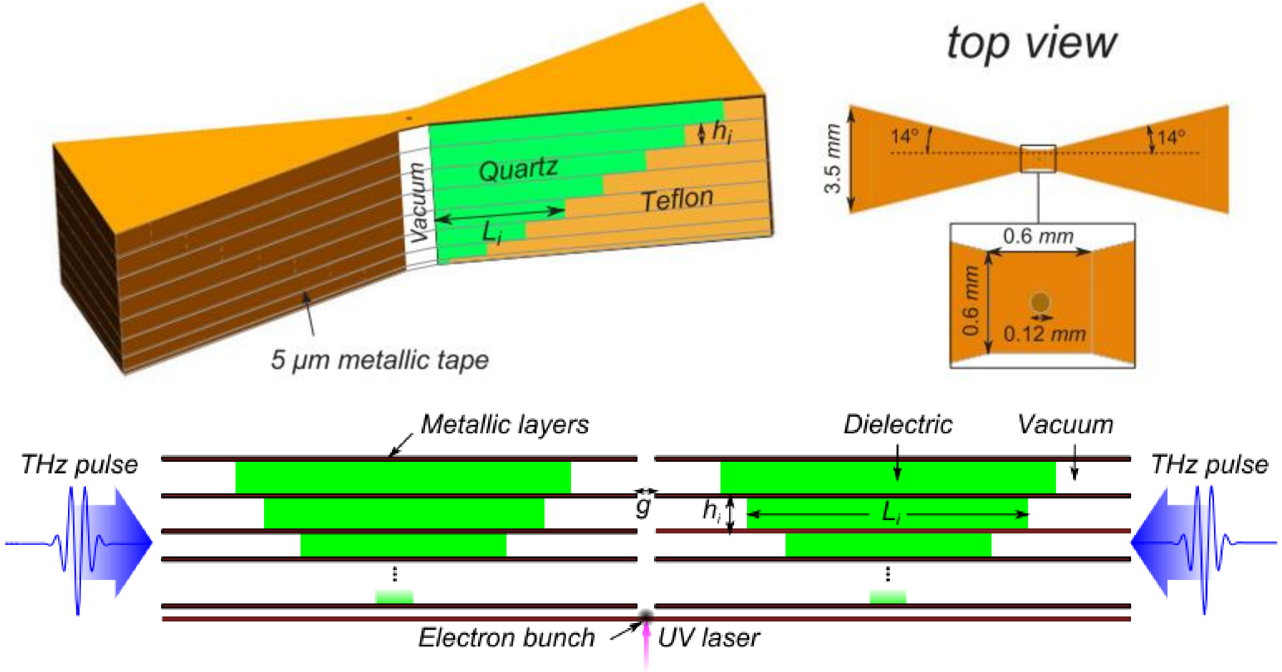


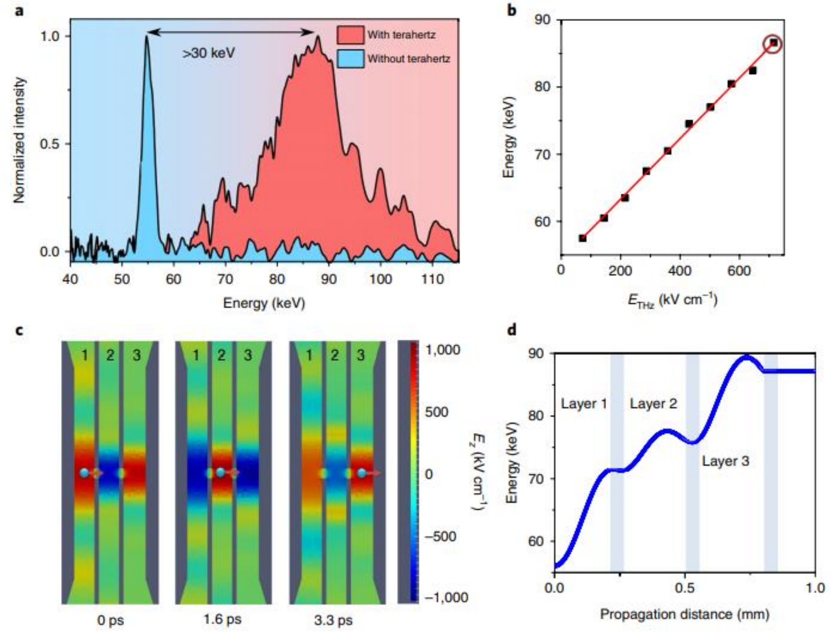
Synchronization by dielectric delay





Experimental Realization





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Short electron bunch generation using single-cycle ultrafast electron guns

Arya Fallahi,[1,*] Moein Fakhari,[1] Alireza Yahaghi,[1] Miguel Arrieta,[1] and Franz X. Kärtner[1,2,3]
[1]*Center for Free-Electron Laser Science, DESY, Notkestrasse 85, 22607 Hamburg, Germany*
[2]*Department of Physics, University of Hamburg, Jungiusstrasse 9, 20355 Hamburg, Germany*
[3]*The Hamburg Center for Ultrafast Imaging, Luruper Chaussee 149, 22761 Hamburg, Germany*

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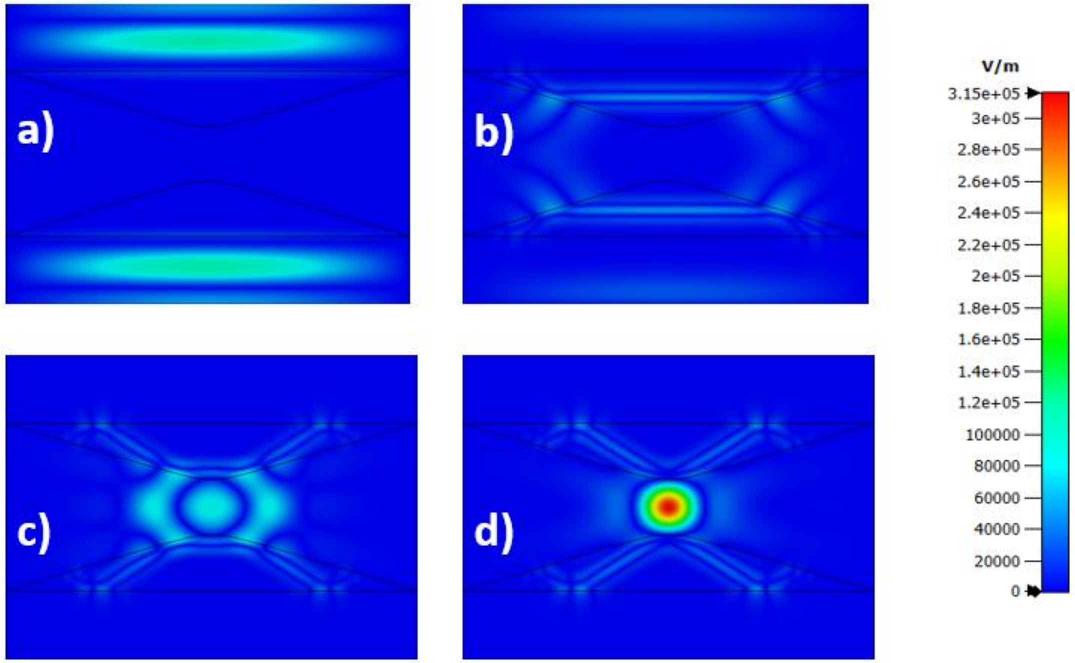
Segmented terahertz electron accelerator and manipulator (STEAM)

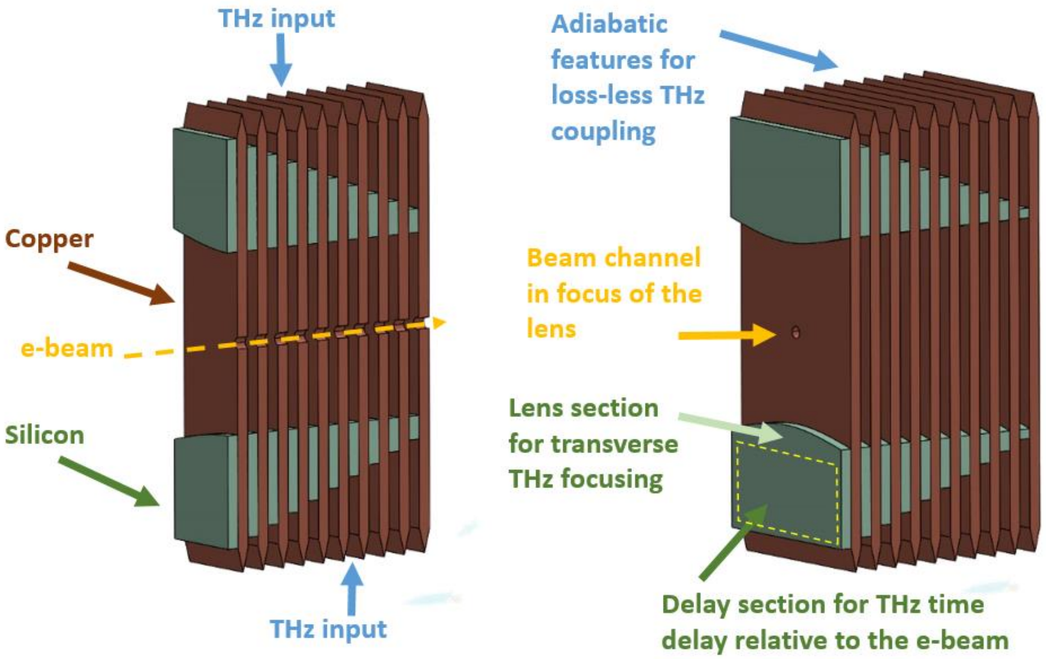
Dongfang Zhang[1,2,5,*], Arya Fallahi[1,5], Michael Hemmer[1], Xiaojun Wu[1,4], Moein Fakhari[1,2], Yi Hua[1], Huseyin Cankaya[1], Anne-Laure Calendron[1,2], Luis E. Zapata[1], Nicholas H. Matlis[1] and Franz X. Kärtner[1,2,3]

Delay line + lens for field concentration

Focusing by silicon lens



Multi-cell structure



Accelerating structure parameters

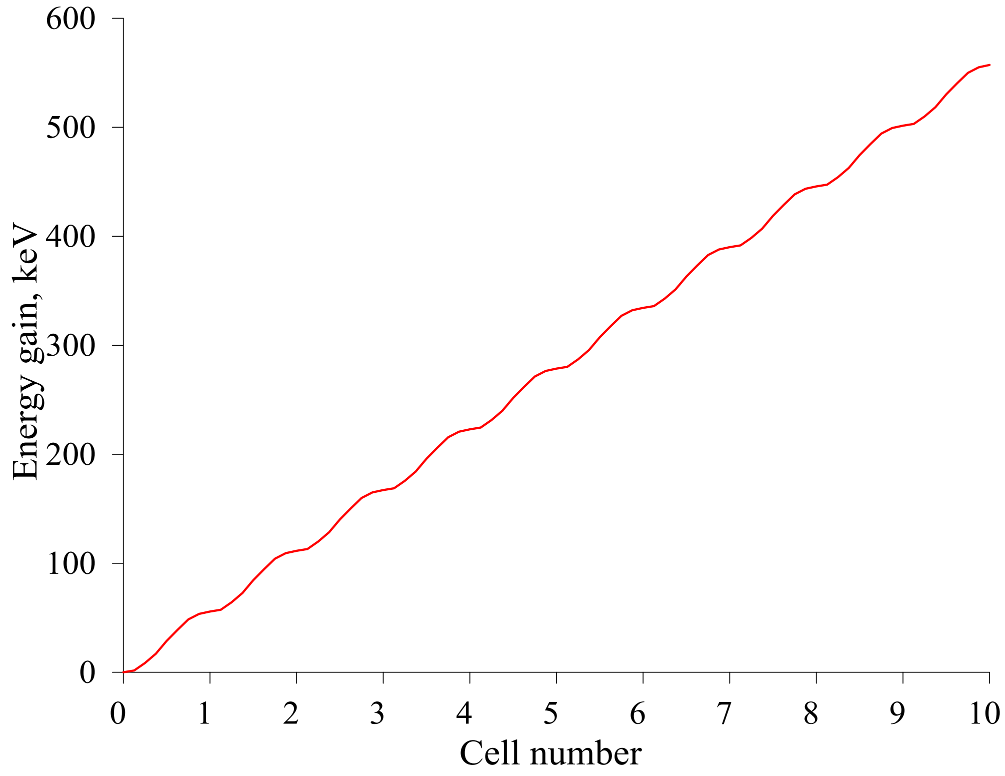
Total input: 116 uJ of THz energy

With total of 10 uJ per cell delivered, maximum accelerating field reaches 385 MV/m.

Table 1: Parameters of THz accelerating structures:

Parameters	Silicon	Quartz
Number of cells	10	10
Dielectric permittivity	11.9	3.75
Cell length	0.2 mm	0.2 mm
Beam pipe diameter	0.1 mm	0.1 mm
Focal length	0.2 mm	0.2 mm
Iris thickness	0.2 mm	0.2 mm
Width	3 mm	3 mm
Length	4 mm	4 mm

Energy gain along the length of the structure



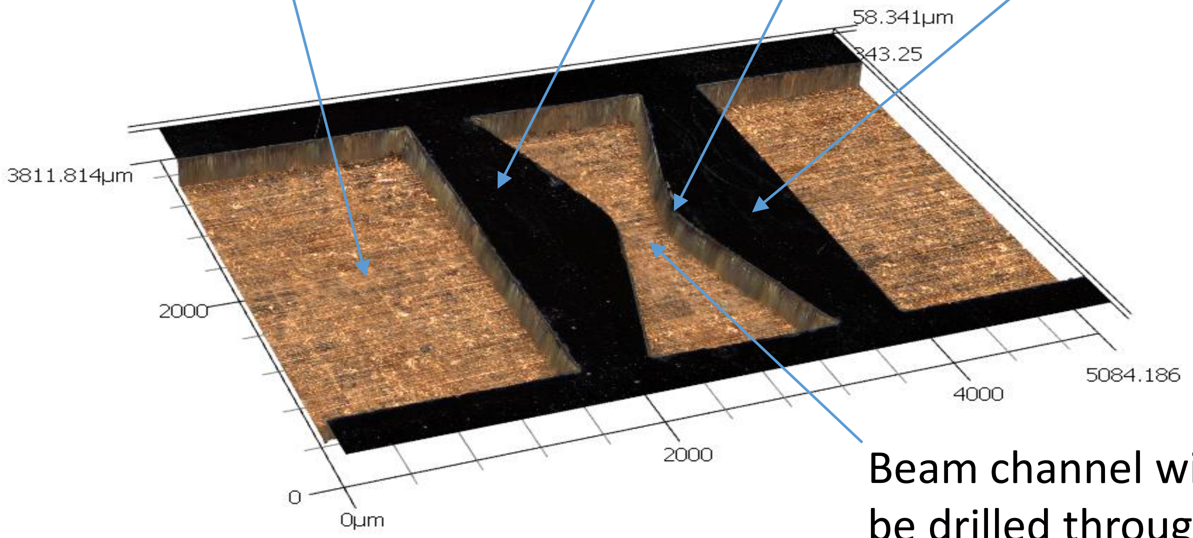
Delay line + lens – monolithic unit!

Copper plate

Silicon

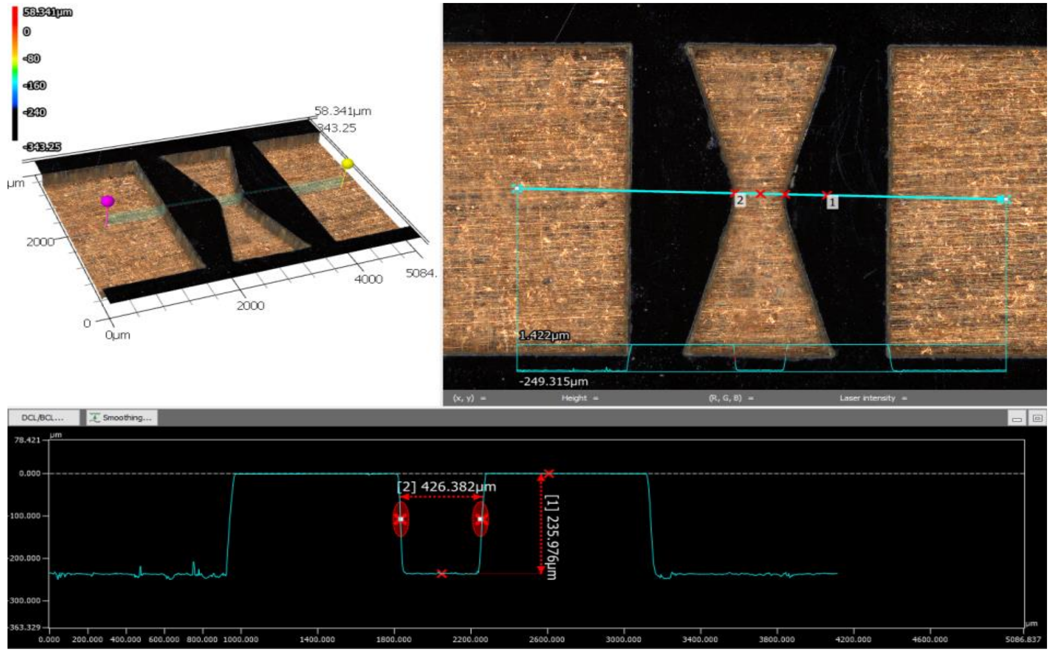
Lens

Delay line



Beam channel will be drilled through here

These units will be stacked on top of each other to form a multi-cell structure…



High Resistivity Silicon cut by femtosecond laser
Metrology: confocal laser scanning microscope (Keyence)