AFAD2026
Asian Forum for Accelerators and Detectors

Dielectric Laser Acceleration (DLA) development at the University of Tokyo

15Oct2026

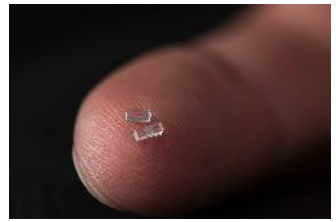
The University of Tokyo
Graduate School of Engineering
Associate Professor　Kazuyuki Sakaue

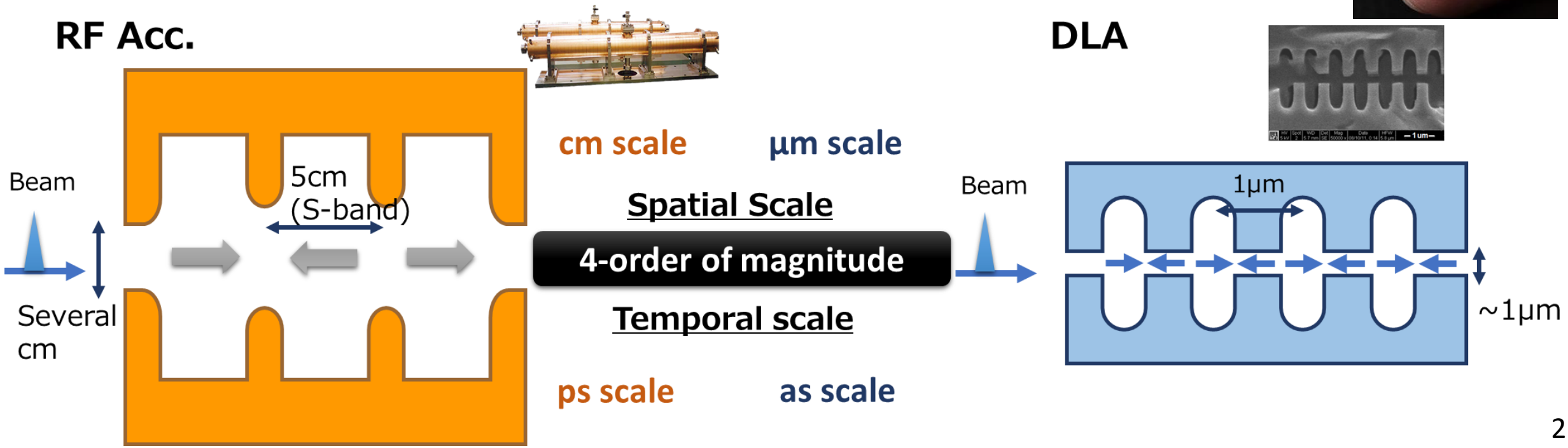
Dielectric Laser Acceleration (DLA)

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Dielectric Laser Acceleration for super-compact accelerator

- Similar with conventional rf accelerator using optical frequency wave
- High gradient and compact acc. is desired from both science and industry
- Attosecond modulated beam is also interesting from accelerator field
- Demonstration of first DLA as a first step in Japan





Changes with DLA technology

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DLA based accelerator

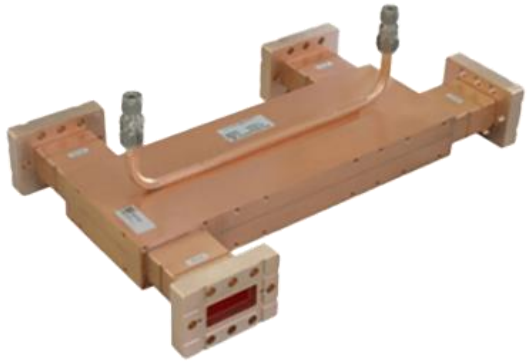
Power source



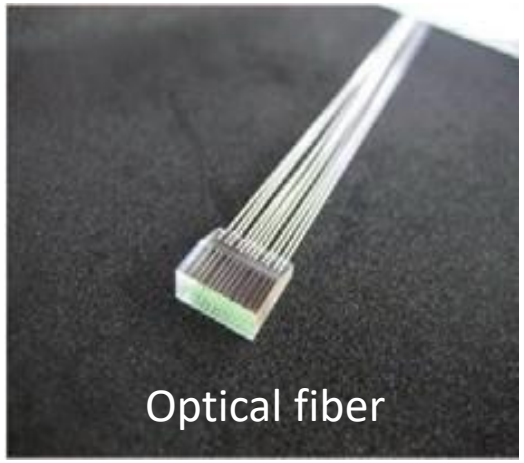
Klystron



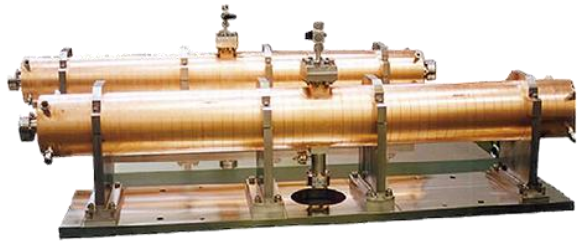
Power delivery

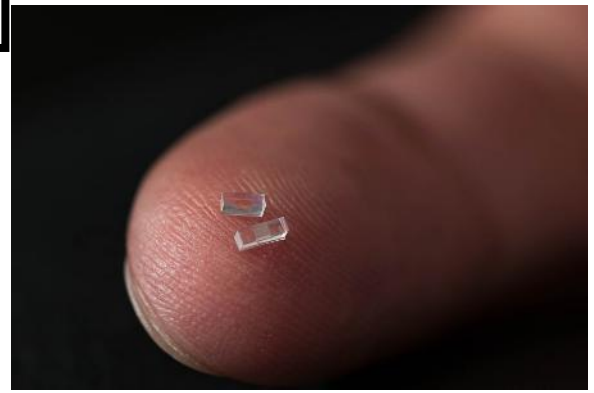


RF Waveguide



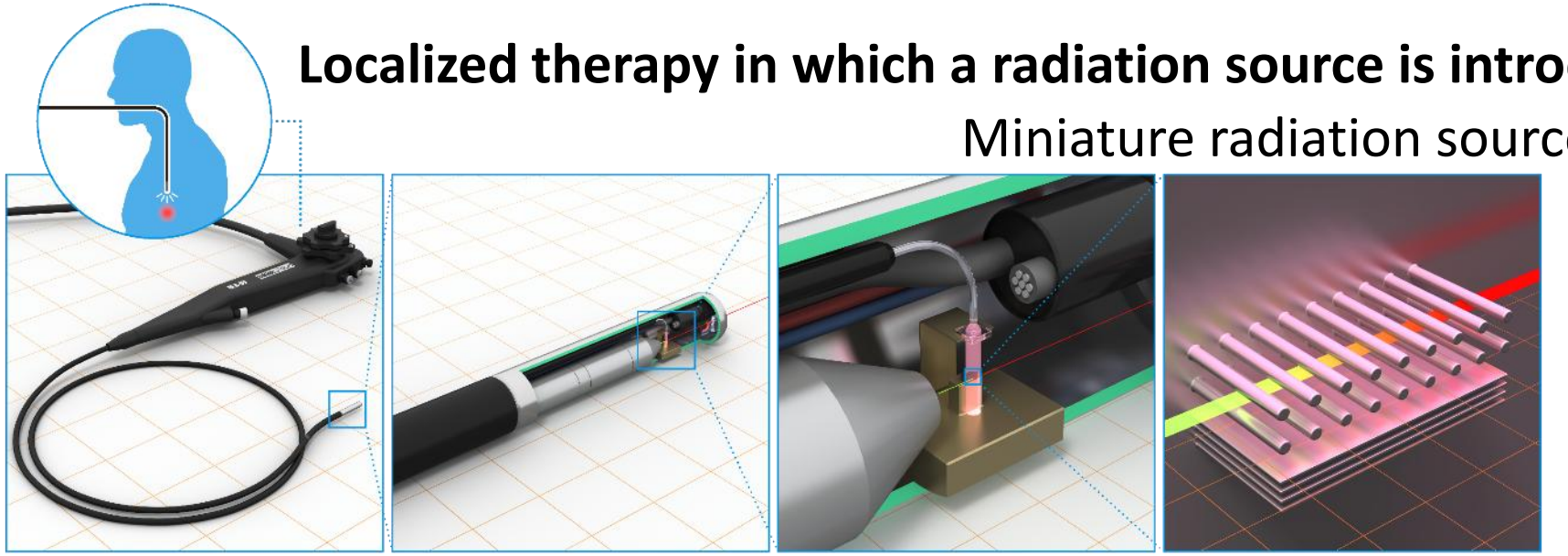
Acc. structure





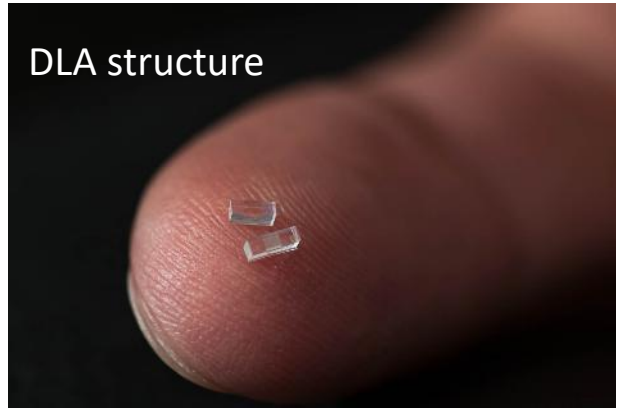
Miniature radiation source

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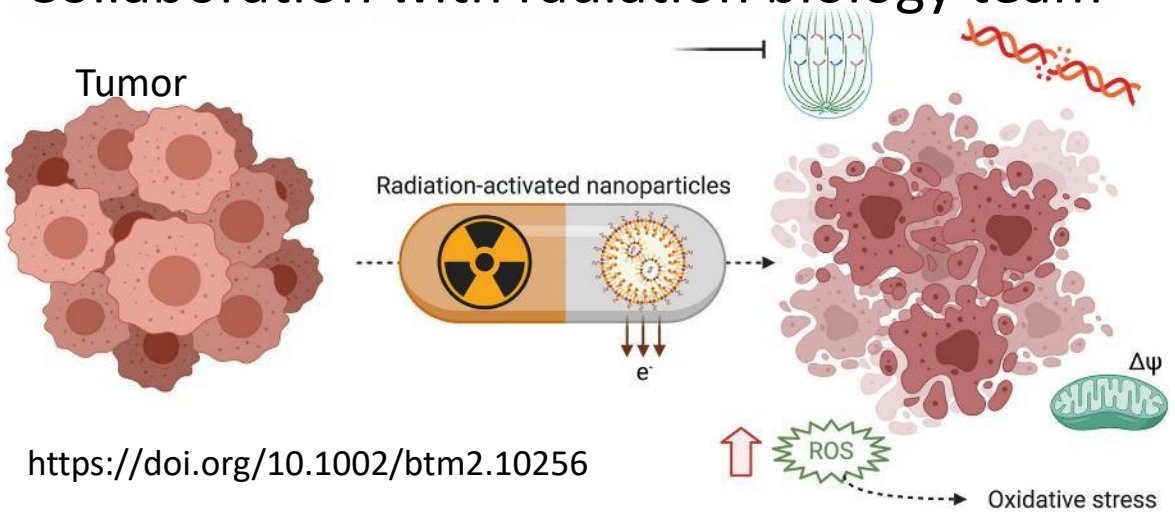


Localized therapy in which a radiation source is introduced into the body

Miniature radiation source (endoscopic cancer therapy)



Collaboration with radiation biology team

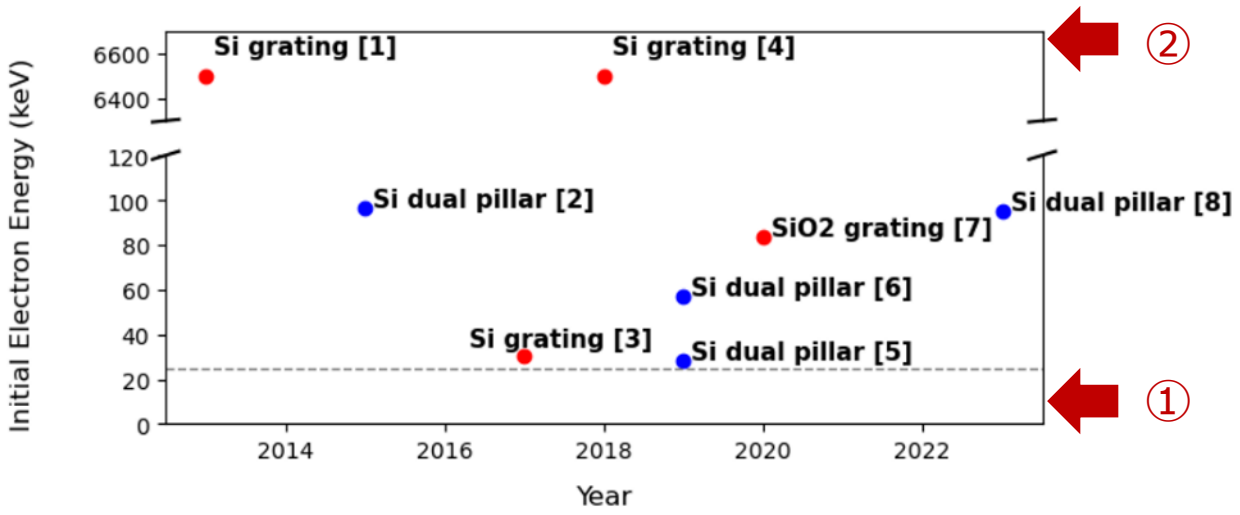


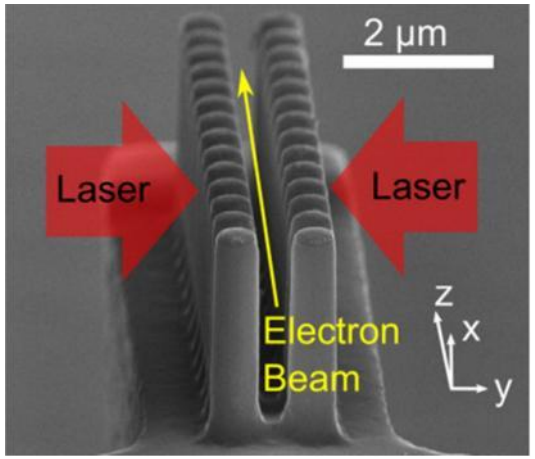
https://doi.org/10.1002/btm2.10256

- **Miniature accelerator mounted on a catheter-guided system**
- **Radiation energy→ Reactive oxygen species**
- **Local, high-density generation of ROS**

  → Induction of cell death
- **Localized therapy, including treatment inside body**
- **Further enhancement is also expected through the concurrent administration of radiosensitizers**

DLA target at saklab UTokyo





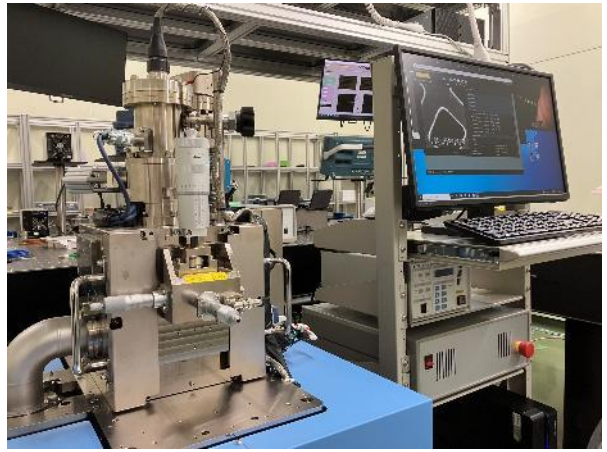
DLA realized in

FAU（Germany）
SLAC/UCLA（US）

Optics Letters, vol. 44, no. 6, p. 1520, 2019

①low energy beam

Accelerate 5 keV β~0.1 electron beam
Lowest energy ever and for miniature electron source



②Relativistic beam

Accelerate 18 MeV β~1 electron beam by pillar structure

➡Realize Acceleration in Japan first (first place in Asia)

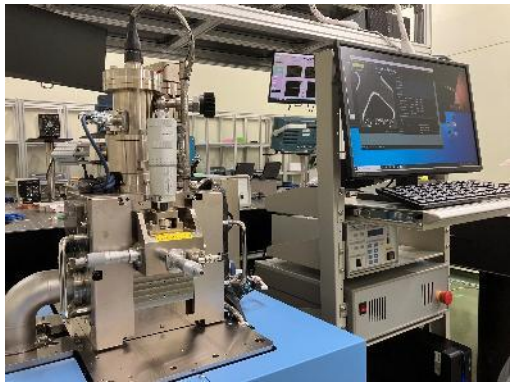


[1] E.A. Peralta et al., *Nature* 503, 91–94 (2013).[2] J. Leedle et al., *Opt. Lett.* 40 (18), 4344–4347 (2015).
[3] M. Kozák et al., *Methods Phys. Res. A* 865, 84–86 (2017).[4] D. Cesar et al., *Phys. Rev. Lett.* 121, 074801 (2018).
[5] P. Yousefi et al., *Opt. Lett.* 44 (6), 1520–1523 (2019).[6] D. S. Black et al., *Phys. Rev. Lett.* 123, 264802 (2019).
[7] V. Sapra et al., *Science 367.6473 (2020)*.[8] P.Broaddus et al., *Stanford* (2023).

Preparation for DLA demonstration

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keV～10 keV
Field emission
electron beam





20 MeV Beam
Photo-cathode
rf linac at UT

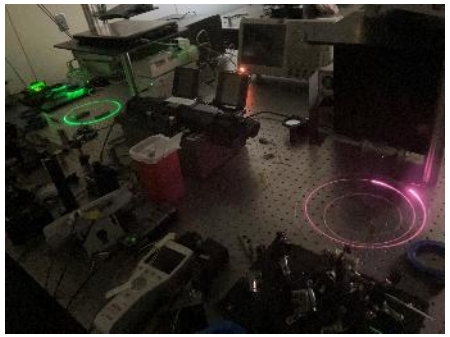
Electron Source

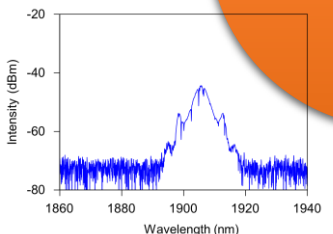
DLA test stand

Drive Laser

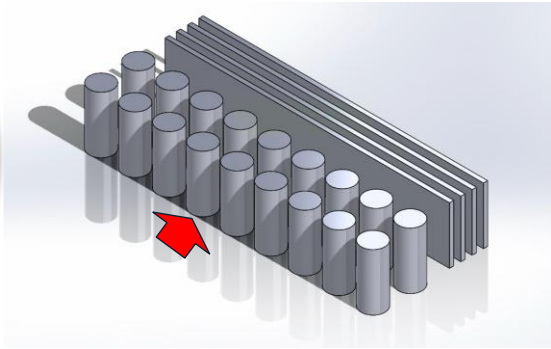
Acc. Structure

Tm fiber laser
(2um wavelength)





Dielectric microstructure
for acceleration
Dual pillars with DBR

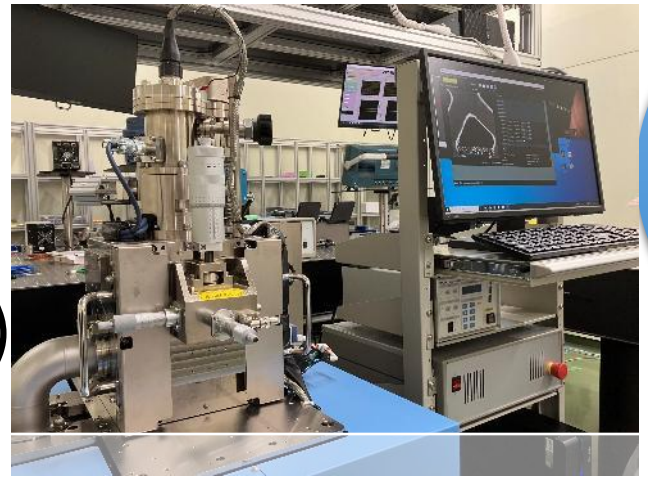


Electron Source (for DLA)

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~ 5 keV field emission electron beam (FE-SEM)

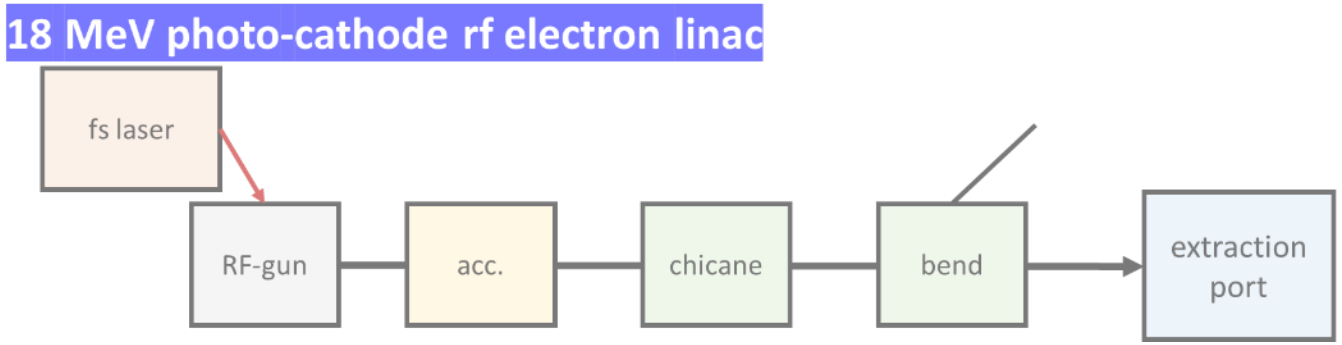
- Alignment with SEM image
- Vacuum stage for DLA
- Energy analyzer (Retarding field spectrometer)

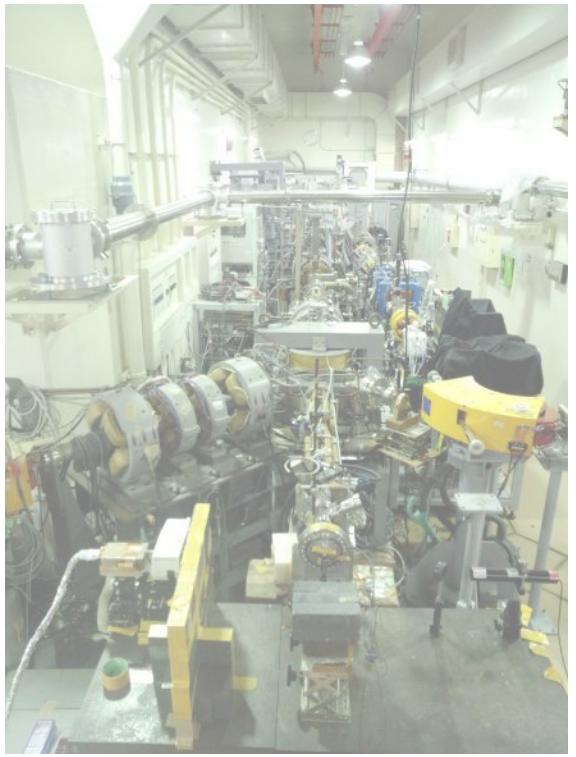


Electron Source

18 MeV photo-cathode rf electron linac at Tokai campus (UTokyo)

- fs electron beam available
- Magnetic beam energy analyzer





Drive laser: Tm fiber laser

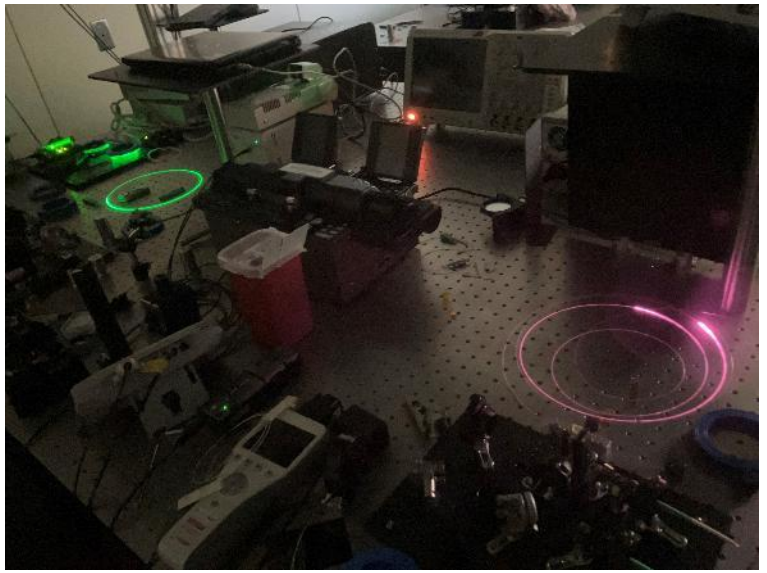
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Drive laser requirements

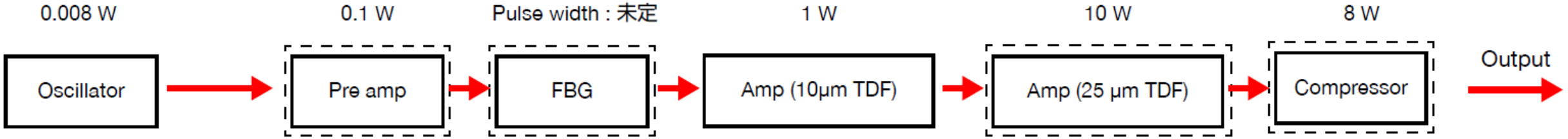
- High efficiency (comparable with klystron)
- Robust and flexible - Compact
- Longer wavelength (acc. size proportional to λ)

➡ **Decide to develop Tm fiber laser system**
(2um wavelength)

Drive Laser



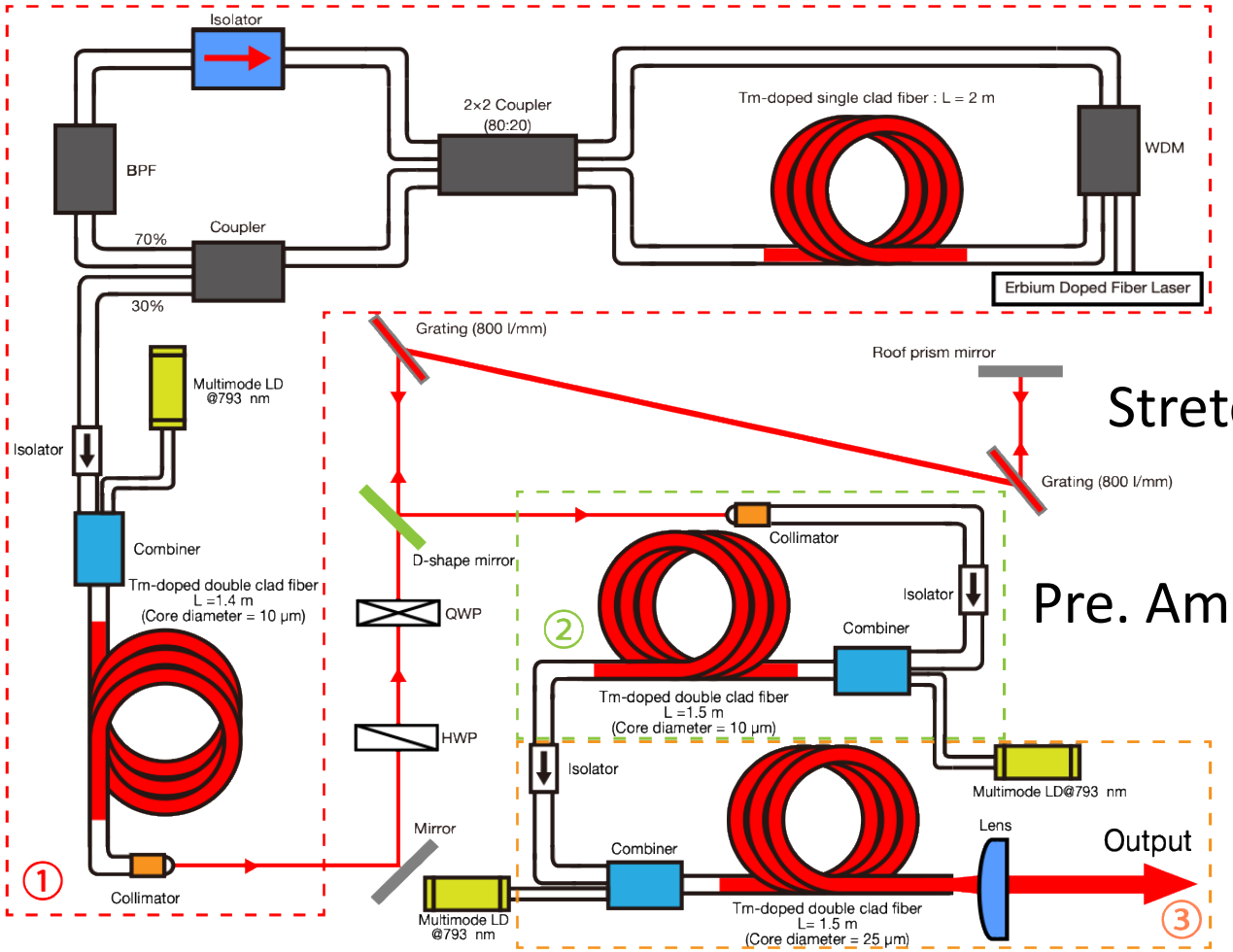
Target:
1950 nm, 1 ps, 1 MHz, 1 W (1uJ/pulse)
w~18um > 0.2 J/cm2 (Expected Si damage threshold)
<Diagram of Tm fiber laser system>



Drive laser: Tm fiber laser

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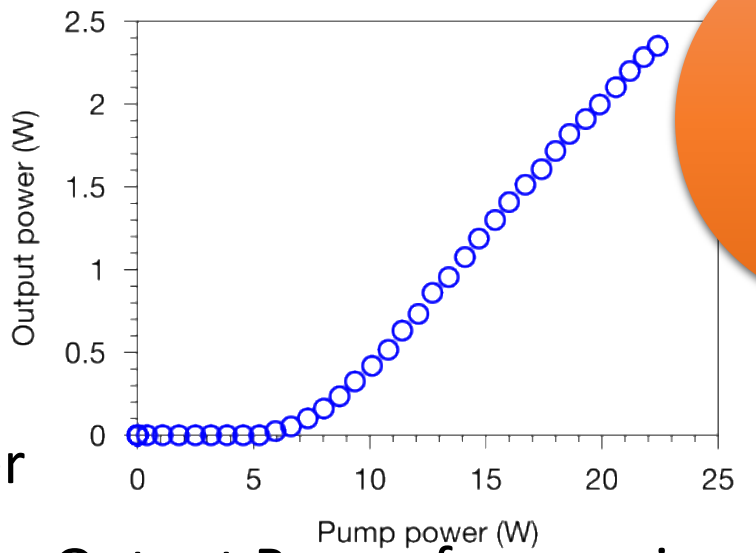
Oscillator



Stretcher

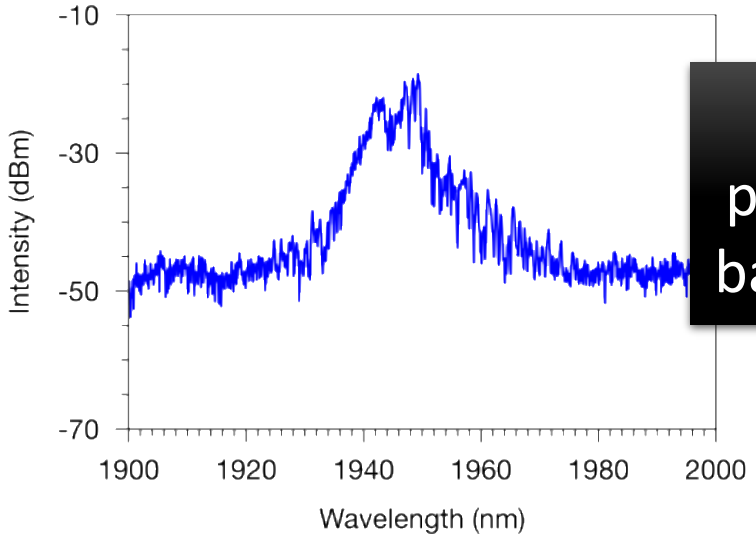
Pre. Amp.

Main Amp.



Drive Laser

Output Power from main amp.



Enough power and band-width

Output Spectrum from main amp.

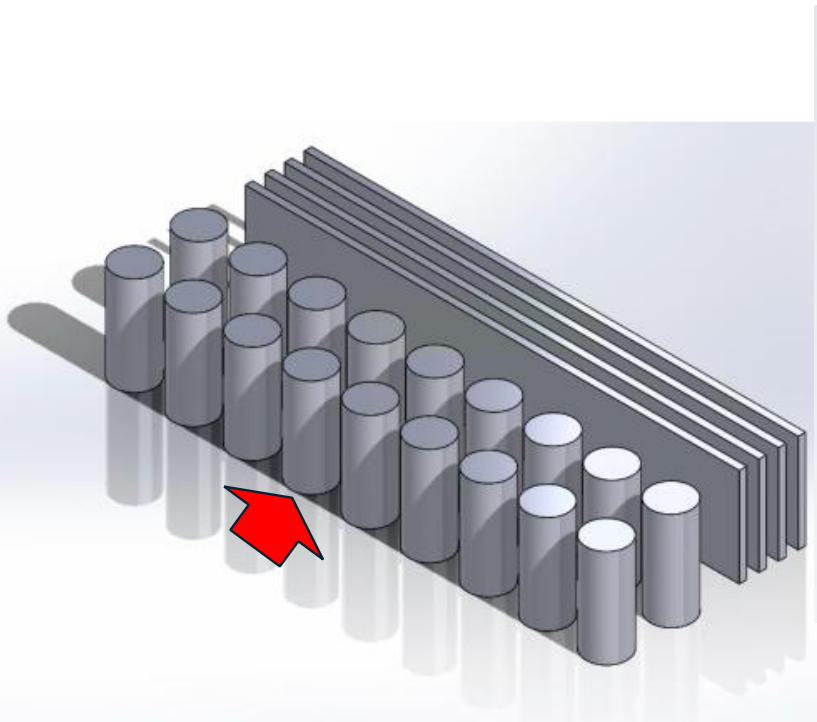
Accelerating Structure

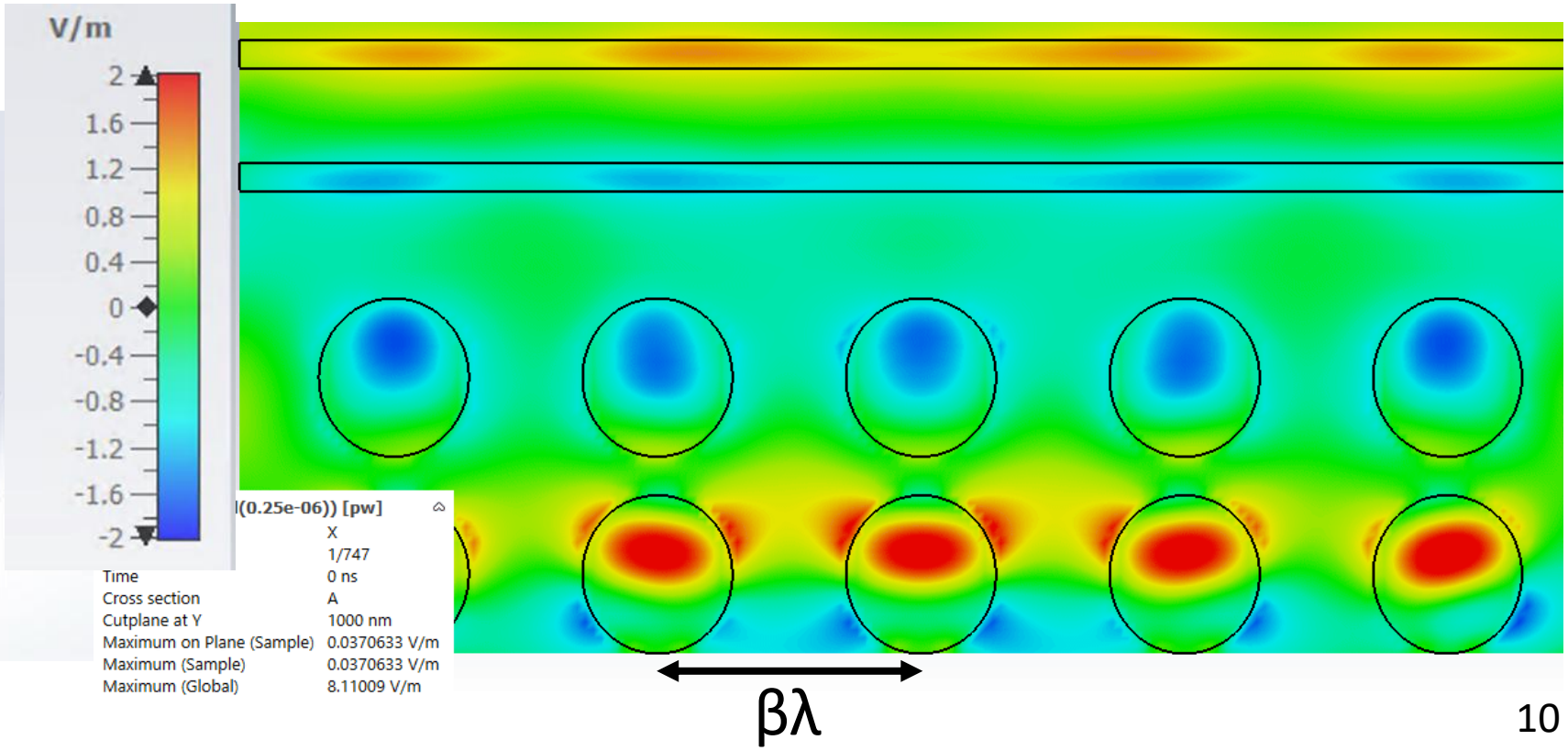
Acc. Structure

Accelerating structure

- Dual pillars (with DBR)
- Made by Si (5 keV)

➡ Using CST Studio and GPT for design





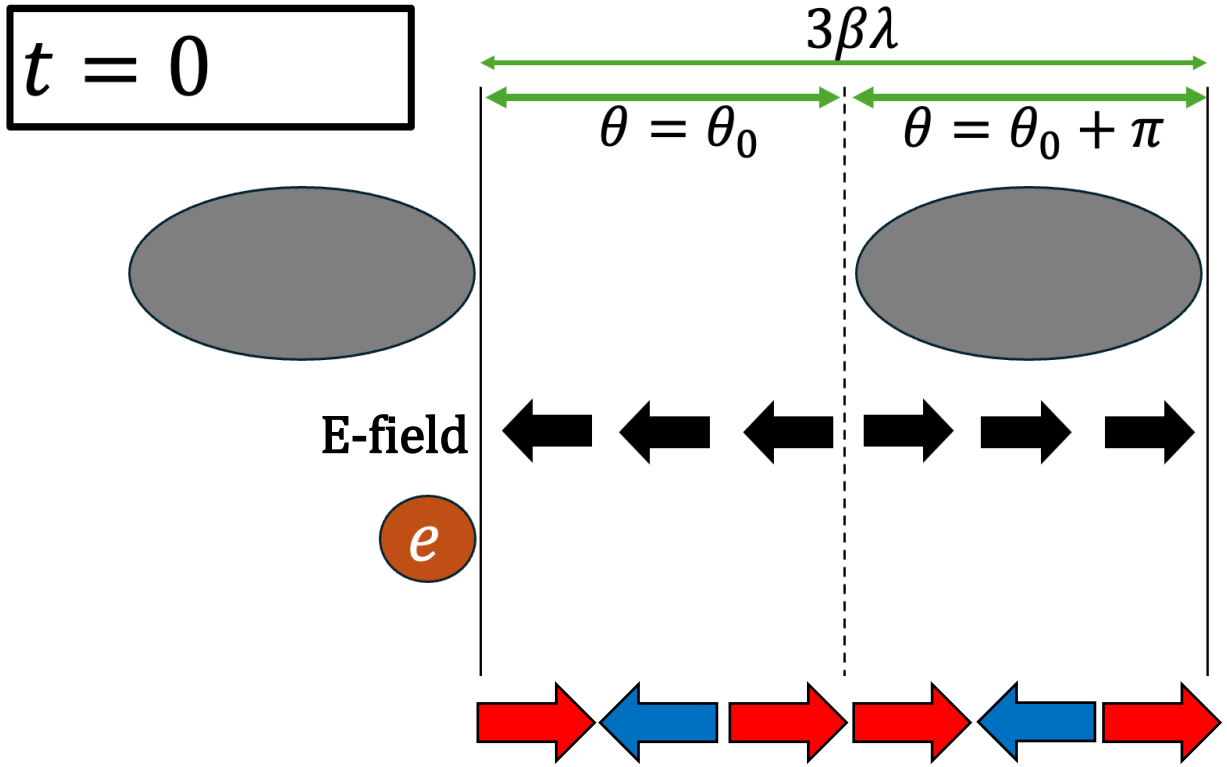
Accelerating Structure (5 keV)

Acc. Structure

Employ 3βλ structure for 5 keV beam

- need 3rd spatial harmonic component of electric field on electron path

➡ elliptical pillar is not suitable

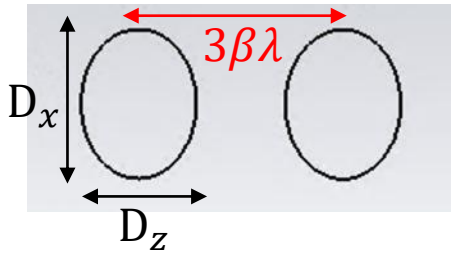


Accelerating Structure (5 keV)

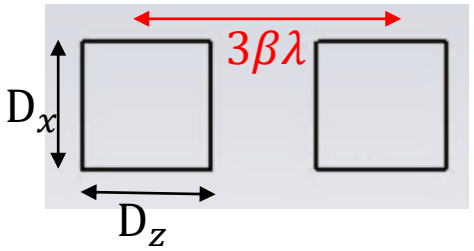
Acc. Structure

Employ 3βλ rectangular pillar structure for 5 keV beam

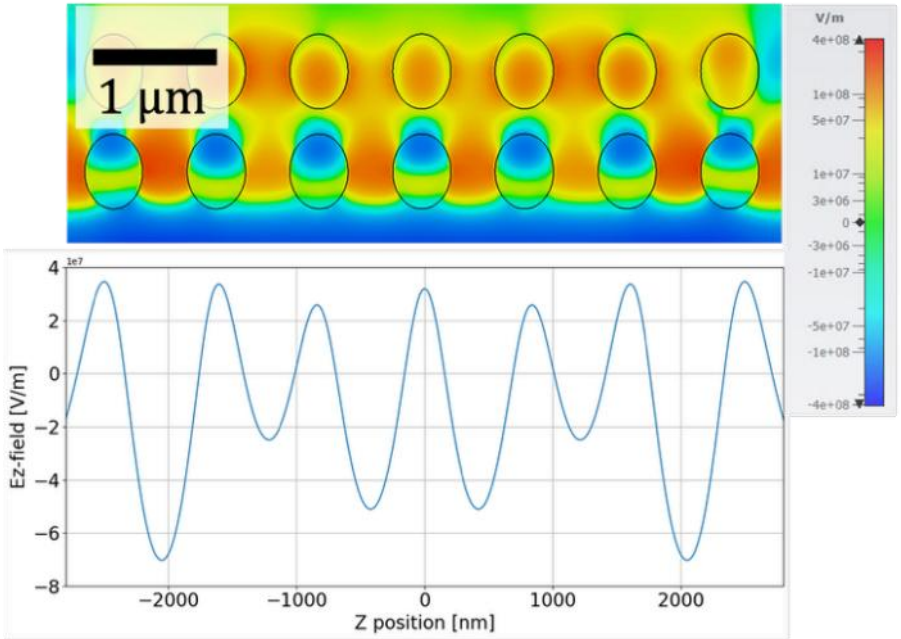
- rectangular pillar increases 3rd spatial harmonic component

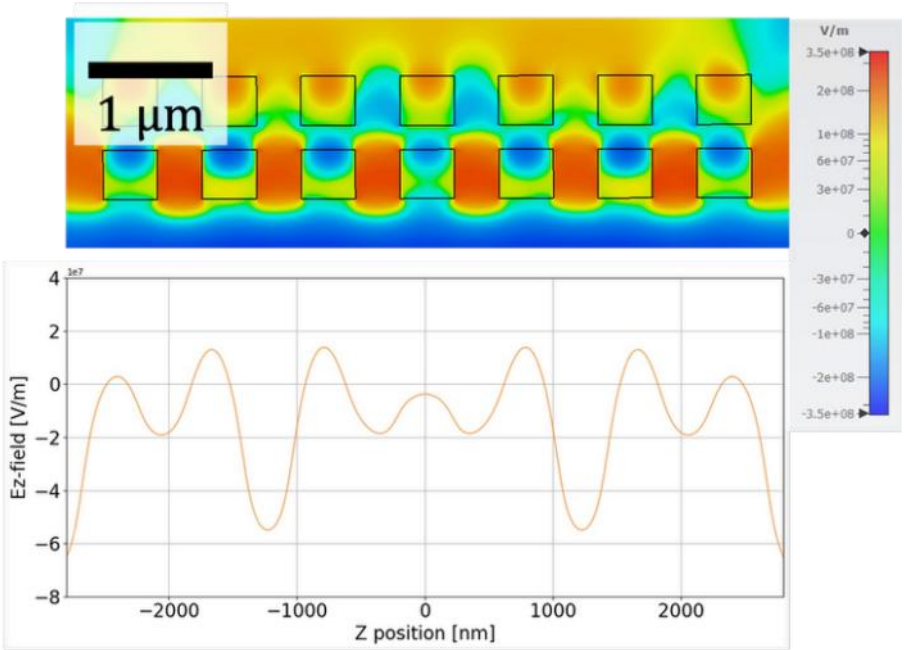


Elliptical



Rectangular





Accelerating Structure (5 keV)

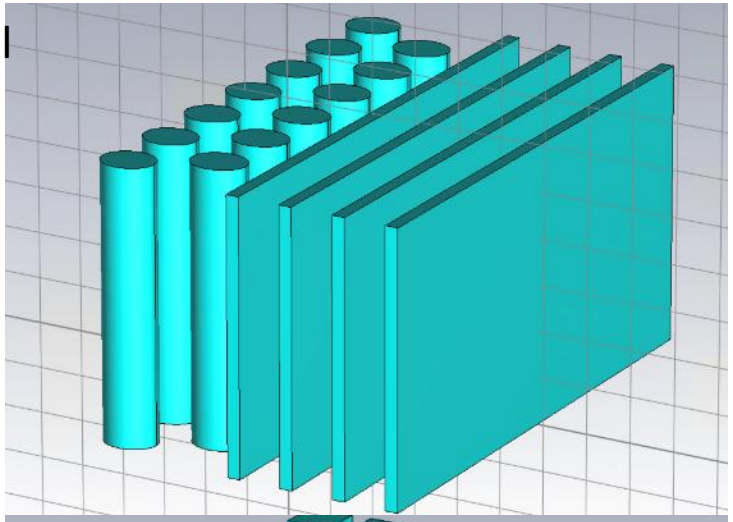
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Acc. Structure

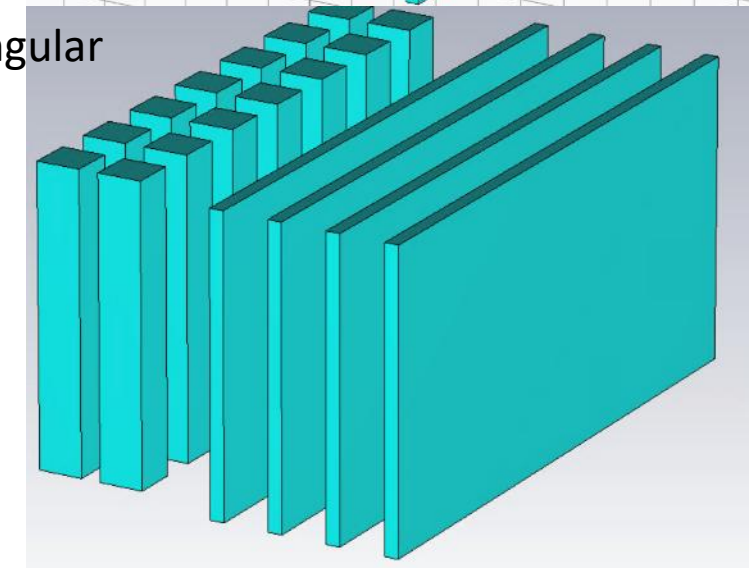
Employ 3βλ rectangular pillar structure for 5 keV beam

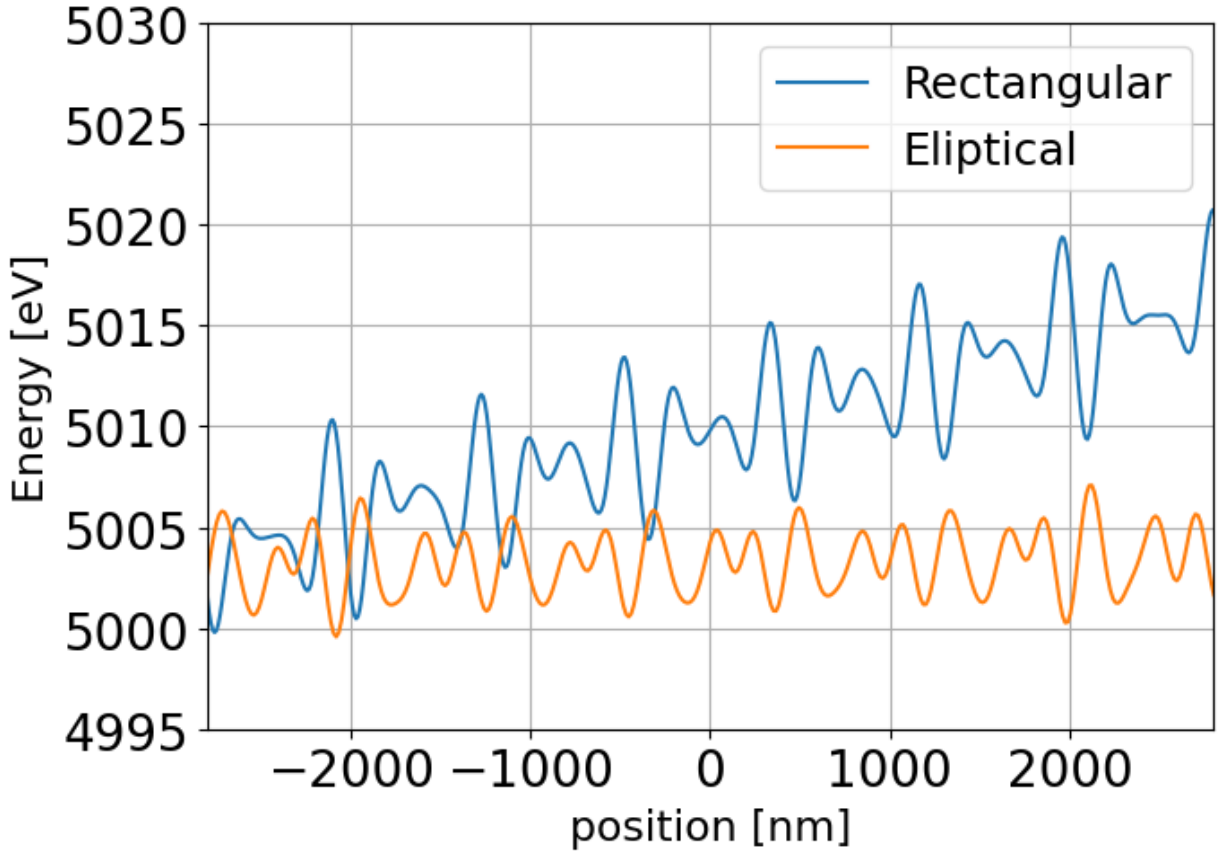
- rectangular pillar increases energy gain

Elliptical



Rectangular





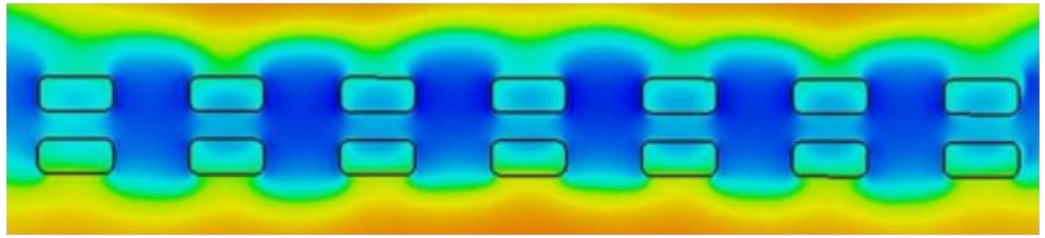
Accelerating Structure (5 keV)

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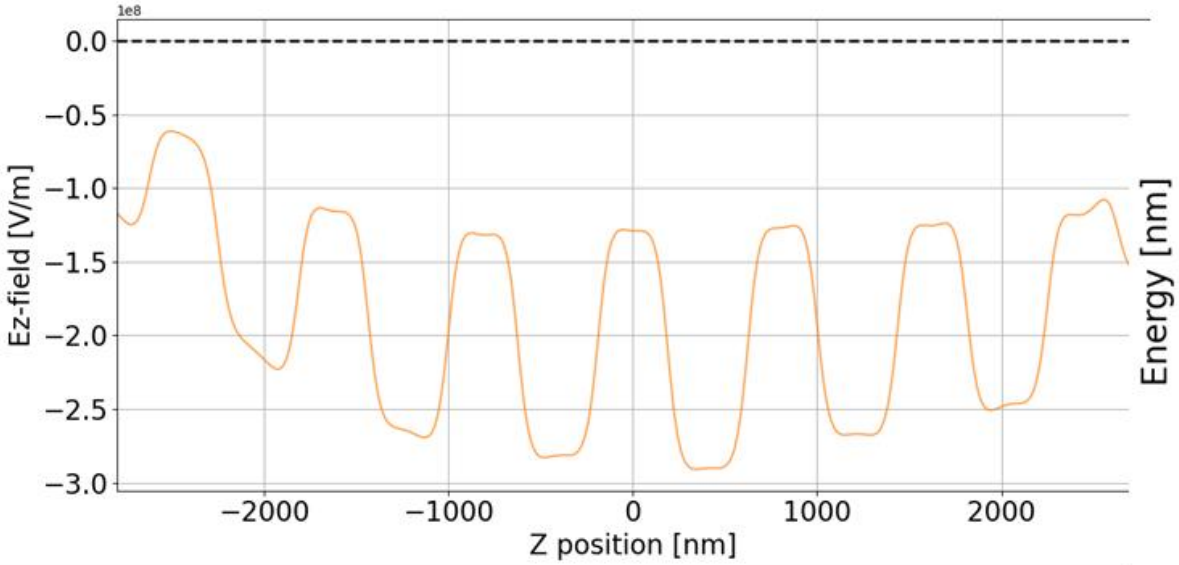
Acc. Structure

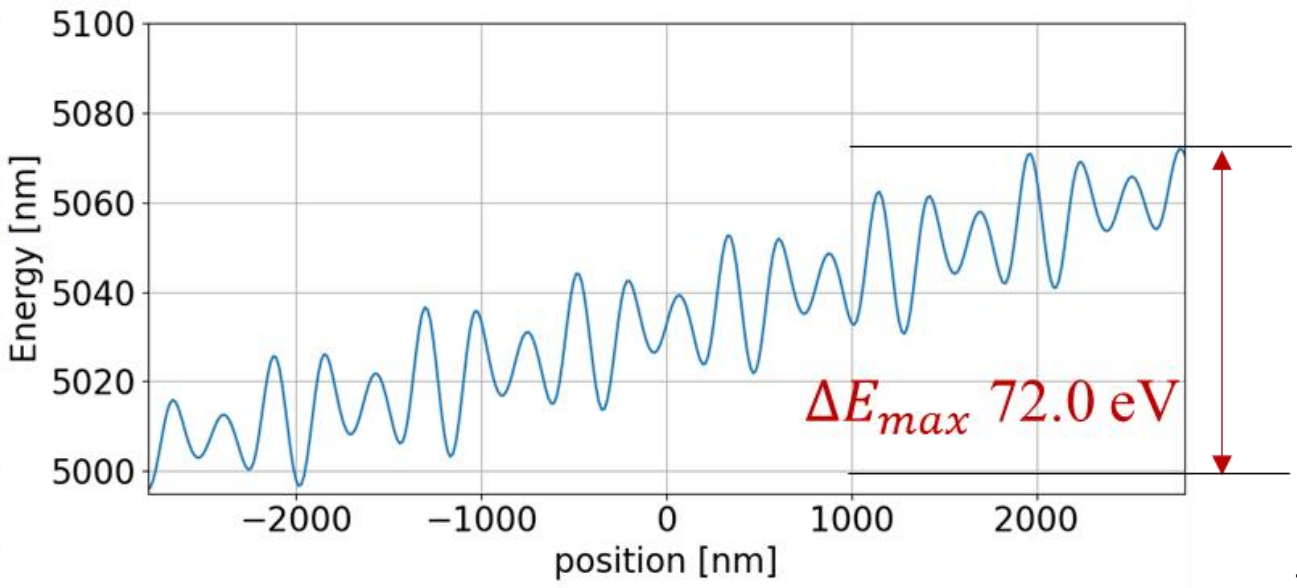
Resulting rectangular structure

➡D_x 186nm/D_z 425nm
72eV gain/7pillar, **12.6 MV/m gradient**





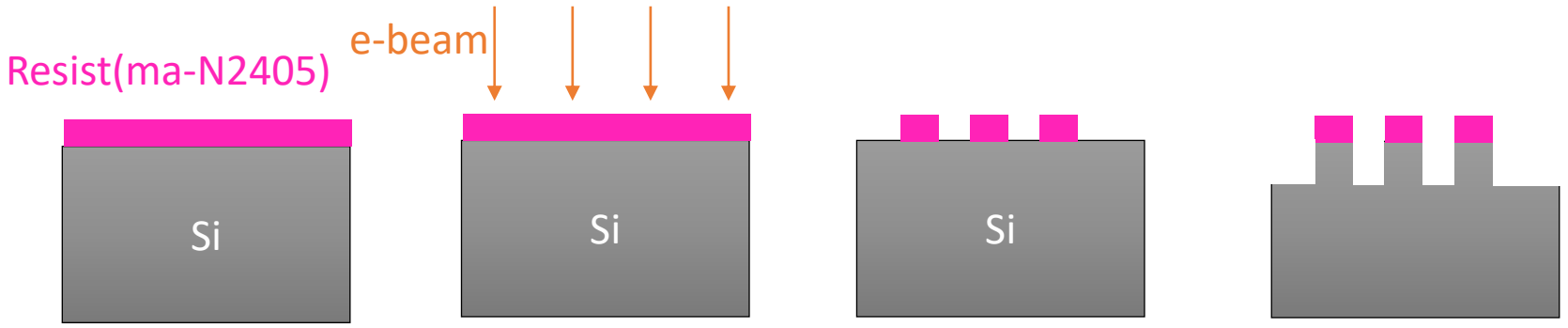




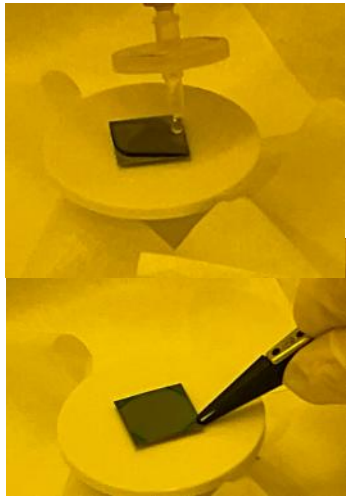
Acc. Structure fab at FAU/Germany

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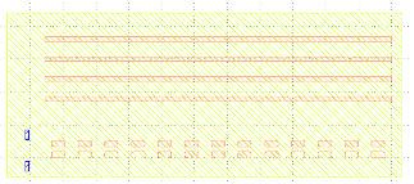
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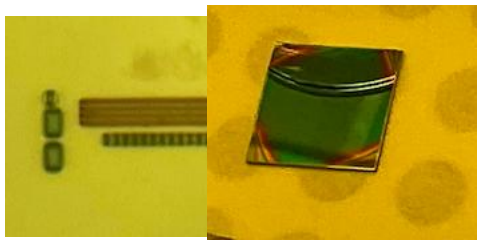


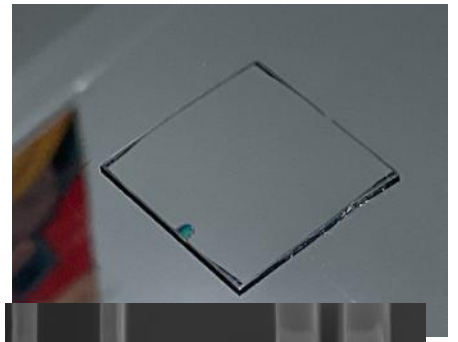


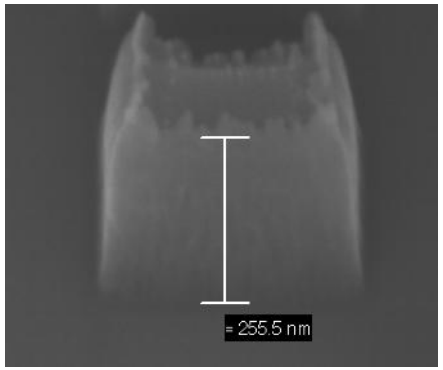


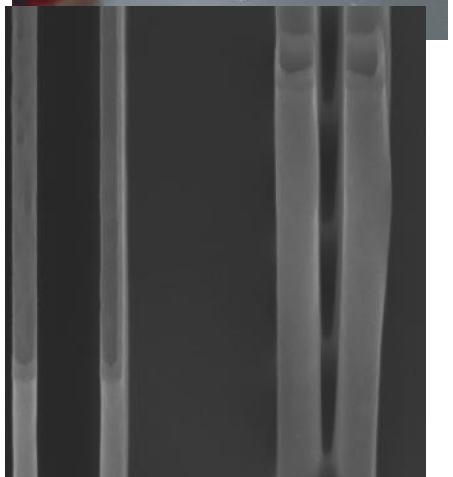










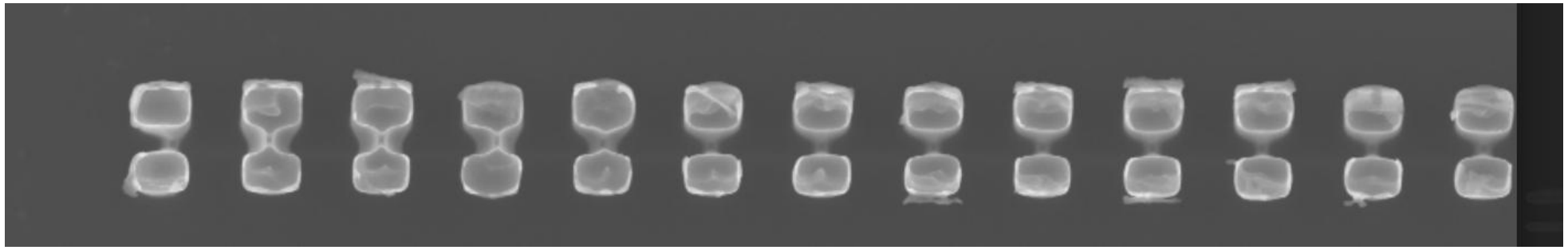




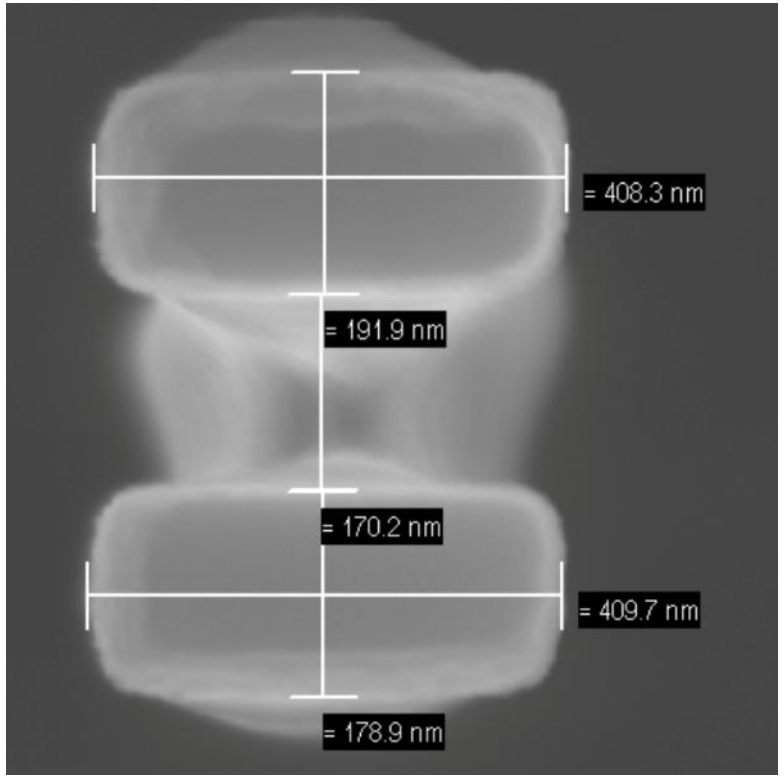
Acc. Structure fab at FAU/Germany

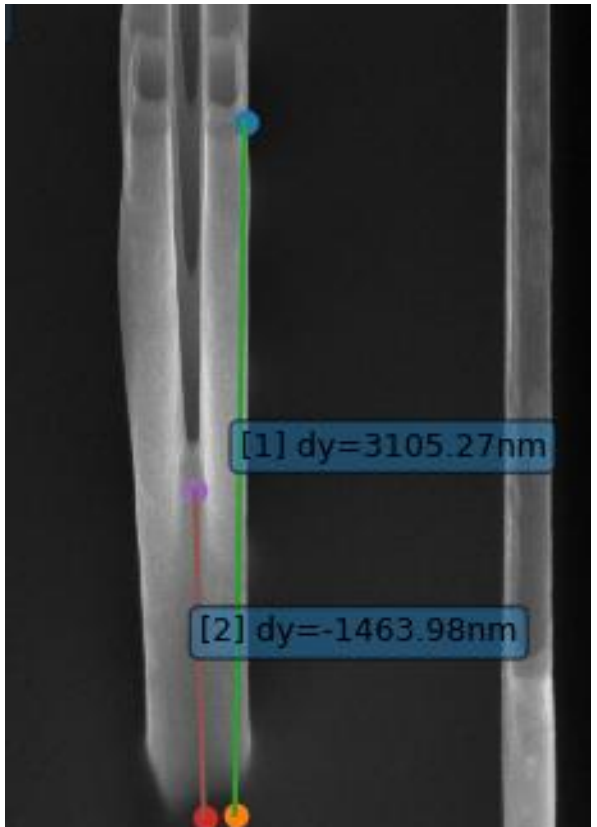
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SEM image of acc. structure



Acc. Structure





Almost designed structures are fabricated with e-beam lithography

Summary and Future prospects

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We are developing a dielectric laser acceleration (DLA).

We are mostly completed to develop 3 key components for DLA
- FE-SEM, photocathode linac (electron source)
- Tm fiber laser (wavelength 2 μm) (drive laser)
- DLA acceleration structure using dual pillars + DBR (acceleration structure)

Research plan

Now we are integrating 3 key components for first demonstration of acceleration in Japan and will start beam test in this several months.

In future, improve gradient, beam current and beam energy, and also try novel structure, new electron source etc