Dielectric wave guide for short electron beam acceleration and compression at THz frequencies

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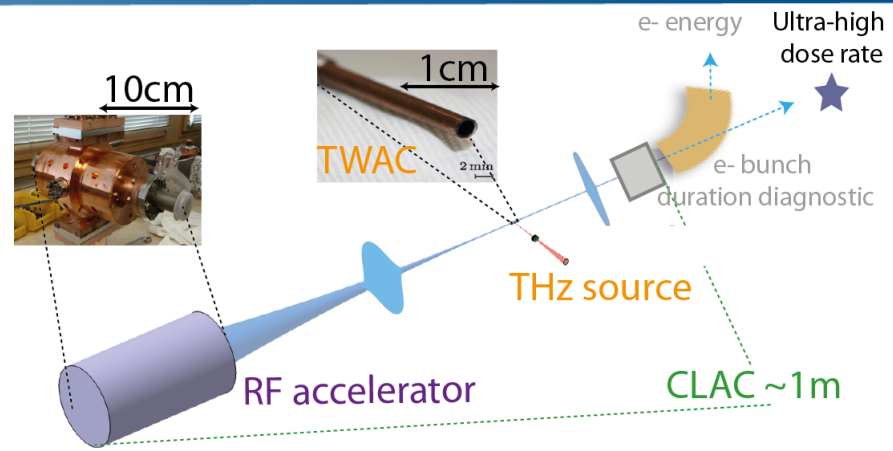
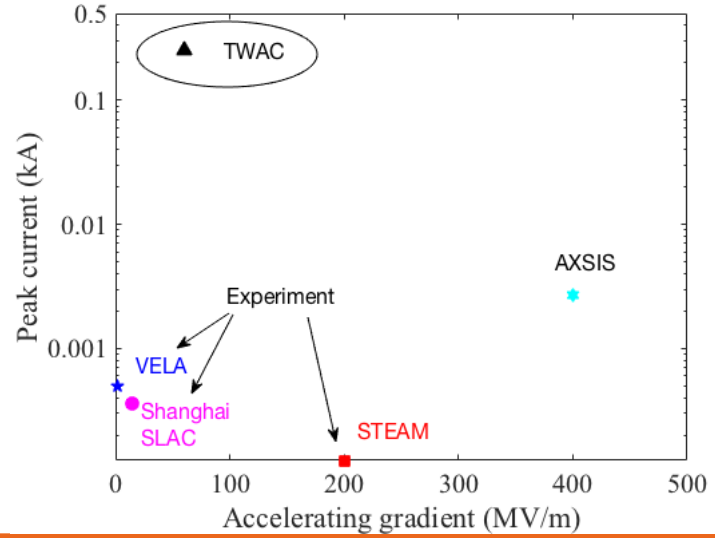
Go towards compact accelerators

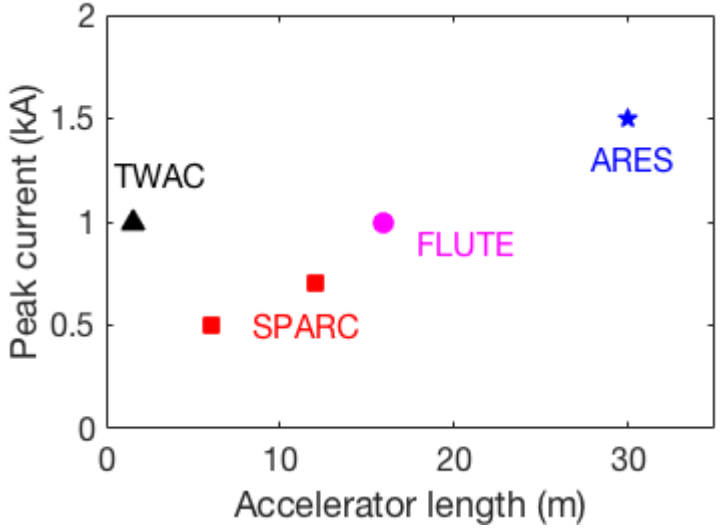
- High gradient
- High peak current
- First prototype of high frequency industrial cavity
- First prototype of a 1-meter scale kA accelerator towards an industrial design



Comparison with THz dielectric acceleration

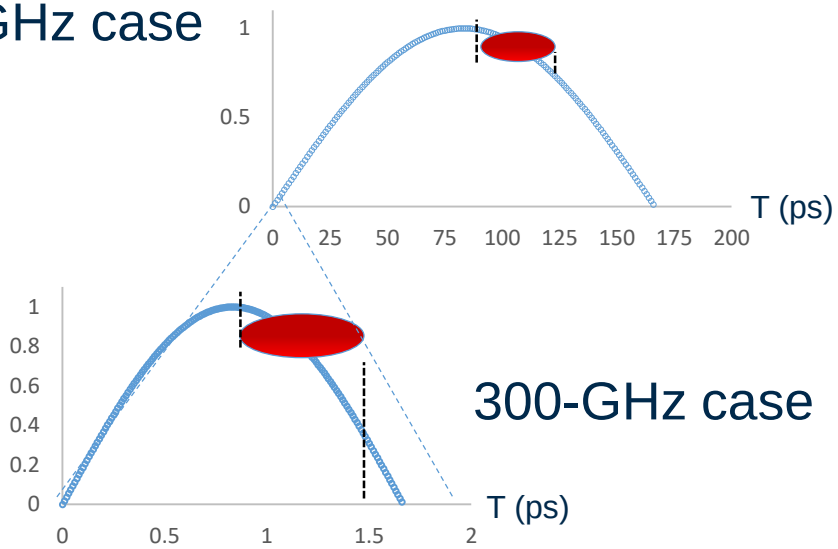


Comparison with RF accelerators



Increasing the accelerating gradient

3-GHz case



300-GHz case

To have high gradient, we need :

- To increase the frequency of the accelerating field
- To have a medium with high level damage threshold
- To adapt the incoming electron source duration to the wave frequency

Acceleration type	Frequency	1.1° of phase	Gradient
Bande S	3 GHz	1000 fs	18 MV/m
Bande X	30 GHz	100 fs	60 MV/m
Dielectric THz acceleration	~300 GHz	10 fs	>100 MV/m
Laser Plasma	~3 THz	1 fs	GV/m

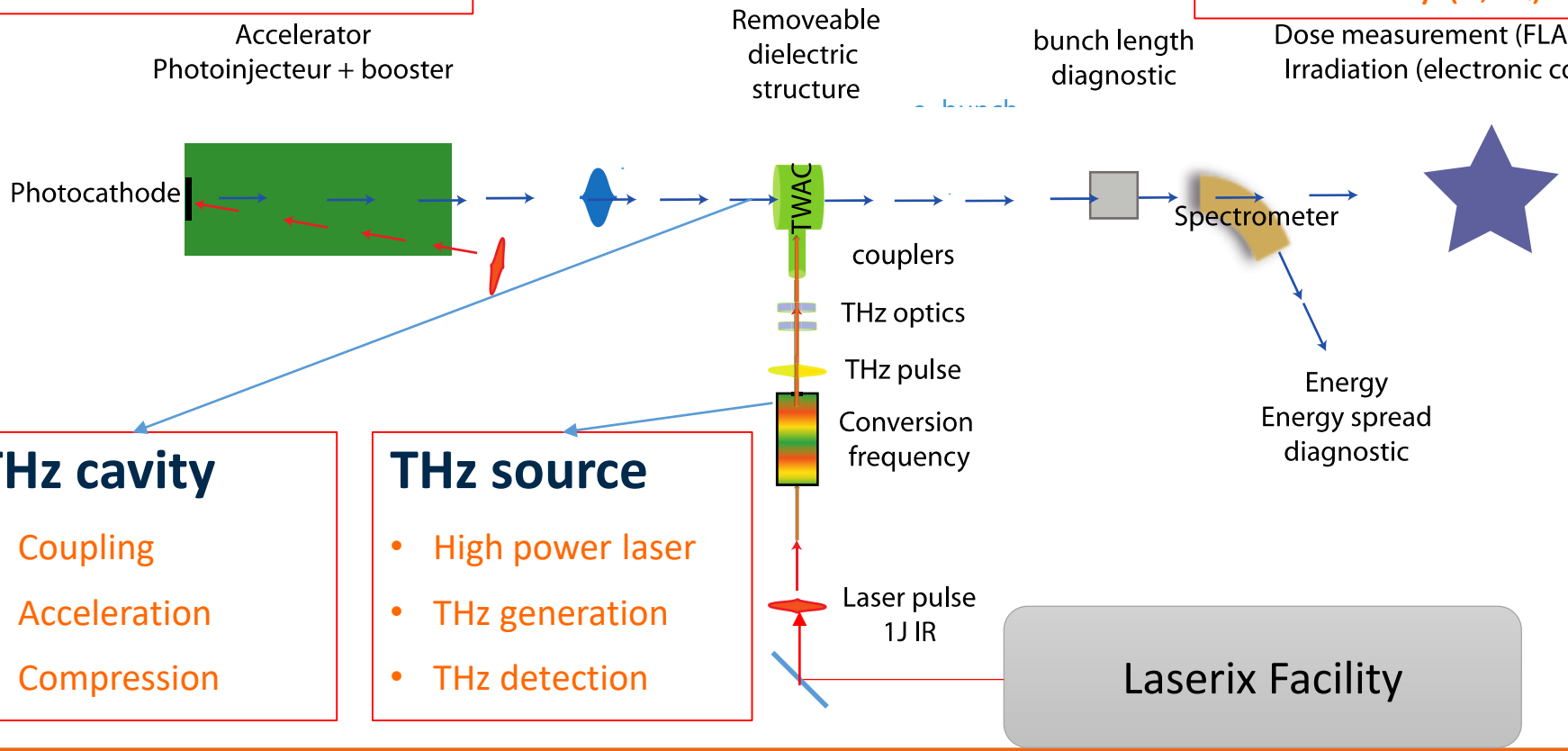
Hybrid prototype accelerator

Accelerator

- Compact (50cm) electron source
- Bunch charge/duration trade-off

Beam diagnostic

- Bunch duration
- Dosimetry (E, Q)



THz cavity

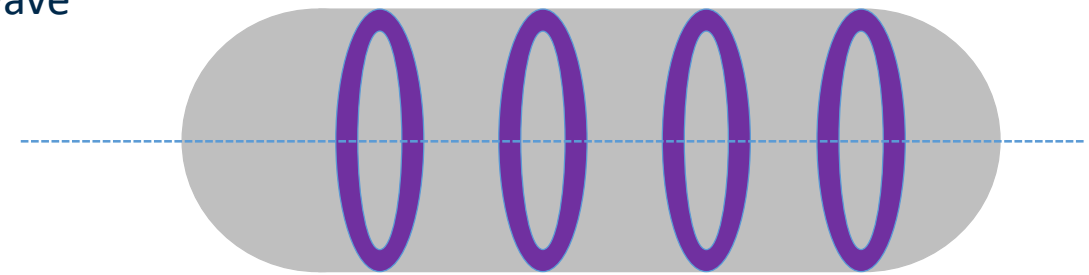
- Coupling
- Acceleration
- Compression

THz source

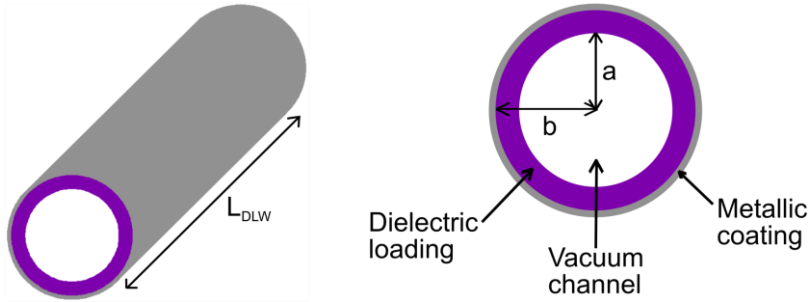
- High power laser
- THz generation
- THz detection

Accelerating THz waveguide

- Why THz frequency
  - Intermediate frequency between RF and laser plasma
  - Can be small enought to be matched with bunch duration from accelerators and high enought to be efficient for high gradient
  - Solid media allows to control acceleration
  - Frequency will force the cavity size
- Circular wave guide are the basis of accelerating cavity to propagate a TM_{01} accelerating mode (radial and longitudinal electric field components)
- But the phase velocity in such a perfectly conducting guide is always larger than the speed of light
- To keep synchronism condition between electrons and accelerating field, we need to slow down the wave



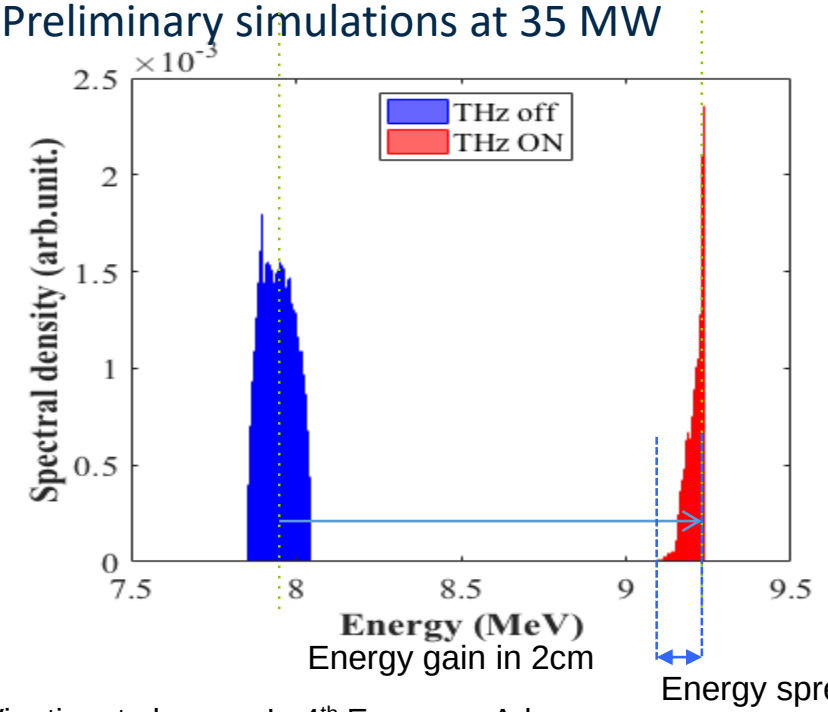
Iris in RF structures



Dielectric in THz structures

Simulation parameters

- We would like to have aperture large enough for beam focusing and machining process
- The frequency should matched with a bunch duration of ~200 fs
- Preliminary simulations at 35 MW



T. Vinatier et al., proc. In 4th European Advance Concepts Workshop (2020)

- To show a full acceleration of the electron beam (no modulation)
- An accelerating gradient more than 100MV/m
- A resulting energy spread smalest than the incoming one (for bunch manipulation)
- To increase the accelerating gradient by increasing the THz conversion efficiency, cascade with increasing frequencies, THz reuse….
- To towards an industrial THz cavity
- To go towards a compact industrial accelerator (all handleable)

Programme

- Simulation of THz Wave-guide and THz coupling
- Study of multi-stage THZ WG accelerator
- Study of THz streaking structure for diagnostic (PALLAS)

Prospectives

- Compare THz generation schemes
- Proposal for CLAC (European Pathfinder call)
- Synergy of PHIL/DRUM and LASERIX facilities
- Installation adapted to test component for accelerators (safety, beam properties, …)

Questions – part 1

1) Where do you see HEP applications of advanced accelerators in 30 years?

2) What intermediate physics applications/steps do you see until a HEP linear collider?

- High gradient structures (stability, reliability, energy spread, …)
- Compact accelerators for industry (medical field, ultrafast science, security, …)
- Free Electron Lasers
- Upgrade existing installation with new technologies

3) What is the synergy with related fields?

- Stability, reliability
- Charge and repeating rate
- Beam dynamics and diagnostics

4) What is the role of your work here?

- High gradient structures
- Propose environment and accessible beam to develop and test components for future accelerators

Questions – part 2

1) What are the important milestones for the next 10 years to get there from today?
   - Efficiency of THz sources for dielectric acceleration
   - Energy spread and stability of the high gradient structures
   - Increase the effective accelerating length (staging, length of accelerating structures, …)
   - Improve the repetition rate

2) What additional support is needed to achieve these?
   - Funding and human resources

3) What should be proposed as deliverables until 2026? Please list in order of priority.

4) Is the R&D work for each of those deliverables already funded and, if not, what additional resources / support would be needed?

Questions – part 3

1) What key R&D needs can be achieved in existing R&D facilities?
   - Improvement of THz sources (stability and efficiency)
   - Optimization of dielectric structures (geometry, length, materials, …)

2) What is the role of the already planned future facilities in Europe and world-wide?
   - TWAC proposal : Terahertz wave accelerating cavity on PHIL/LASERIX facility

3) What can be done with the existing and planned funding base?

4) Is a completely new facility needed?
   - Existing facilities allow developing mentioned research and can benefit directly from these advances

5) Are additional structures needed beyond existing networks and projects, e.g. a design study for a collider or an advanced accelerator stage?