radiabeam TECHNOLOGIES

ATF experience from a small business angle

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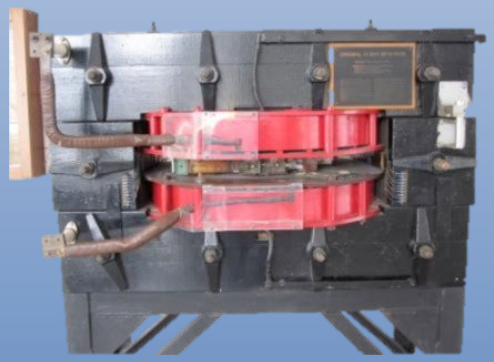
Brookhaven National Laboratory

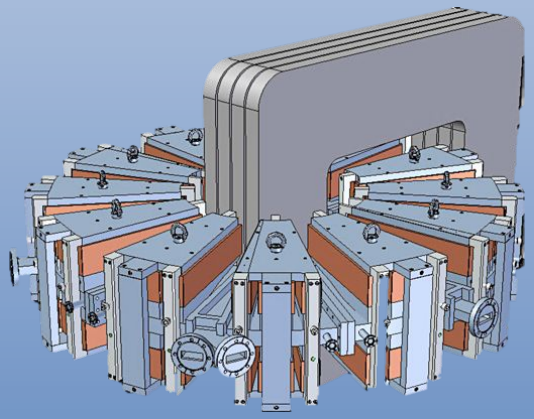
Outline

- RadiaBeam overview
- What is a small business angle?
- How can ATF help our mission?
- Case studies:
  - RF capabilities
  - Beam profile diagnostics
  - High power compact ICS program (STINGray)
- Conclusions

Company background

- RadiaBeam Technologies was founded in **2004**, a spin-off from UCLA Particle Beam Physics Laboratory
- Initial business idea was to develop a ***Radiatron***, a high duty cycle FFAG betatron, for industrial applications.



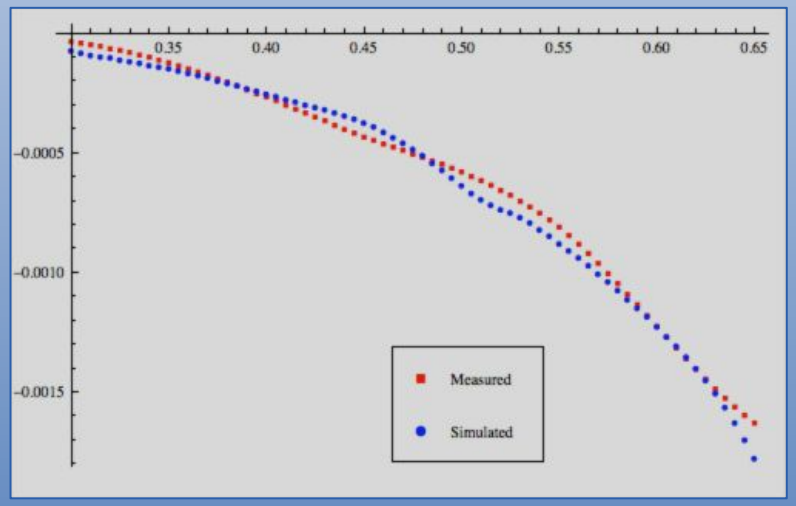


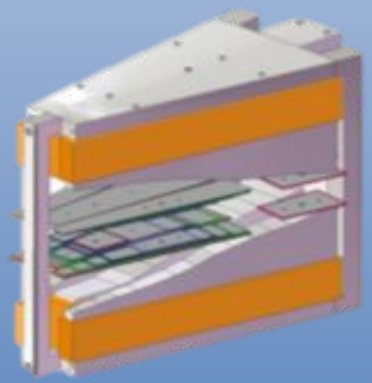
Radiatron development

- DOE SBIR grant to develop a prototype system (6 MeV, 10-20 kW average power)
- 2004-2005: beam dynamics design/engineering
- 2006-2007: prototype construction

Radiatron development

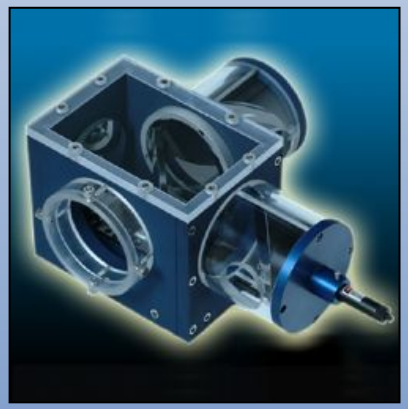
- 2007: ran out of funds
- the biggest unresolved technical challenge was FFAG magnets and extraction
- *IBA s.a.* became interested in Radiatron
  - Offered access to IBA codes to study extraction
  - Funded magnets redesign (no success)





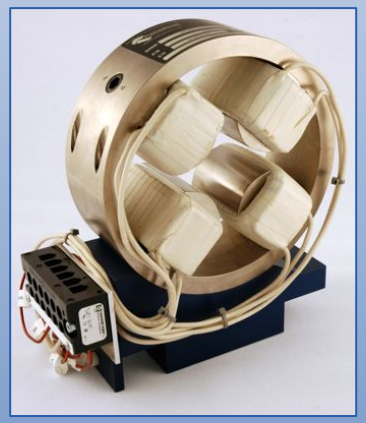
Products

- 2009: IBA funding ran out, Radiatron development had to stop
- Fortunately since foundation we tried to develop and sell other products (longitudinal and beam profile diagnostics, magnets, RF structures).



1st product sold (2004): THz interferometer for bunch length measurements (licensed from U. of Georgia); delivered to *INFN*

2nd product sold (2005): quadrupole triplet for low energy beamline; delivered to *Accuray*



- SBIR Program also offered multiple new opportunities (products/R&D – positive feedback)

Present status

- Currently over 40 employees, including 8 PhD scientists

Small business angle?

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- How is small businesses (SB) is different from research institutions (RI):

	RI	SB
What defines the tasks?	• Scientific curiosity • Society needs	• Demand
Nature of work	• R&d • Experiments	• r&D • Production
What is the metrics of success?	• Scientific impact • Publications/capabilities	• Profit • Growth

Small business angle?

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What is the metrics of success?	• Scientific impact • Publications/capabilities • Stable Funding	• Profit • Growth • Stable Funding

Small business angle?

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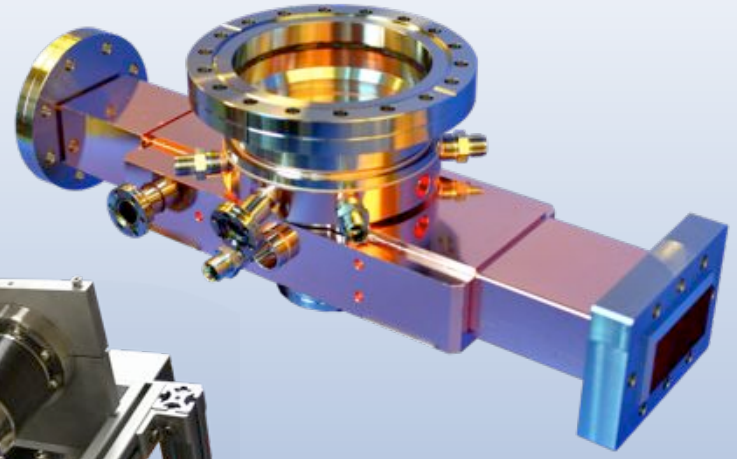
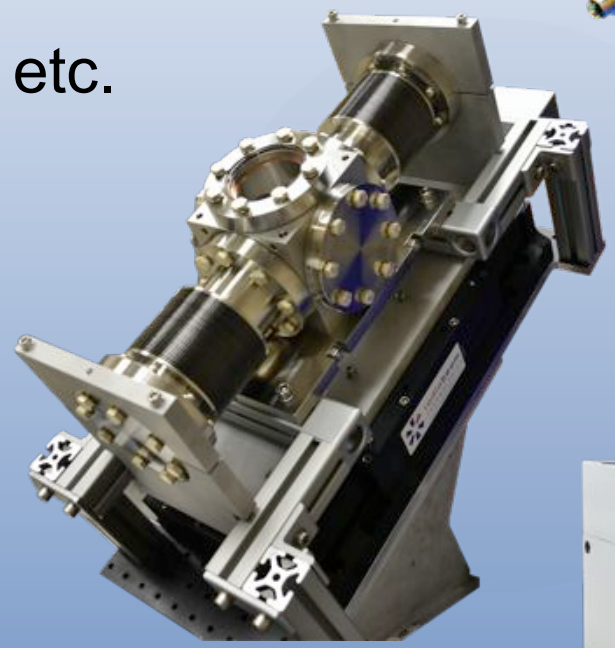
- In the field of Accelerator Science and Technology SB and RI are often part of the same community
- DOE SBIR and Stewardship programs facilitate close programmatic ties between SBs and RIs

- The most important and unique aspect of small business experience is ***development, marketing and sales of products***
- How can ATF help us to get a competitive edge?

Research products

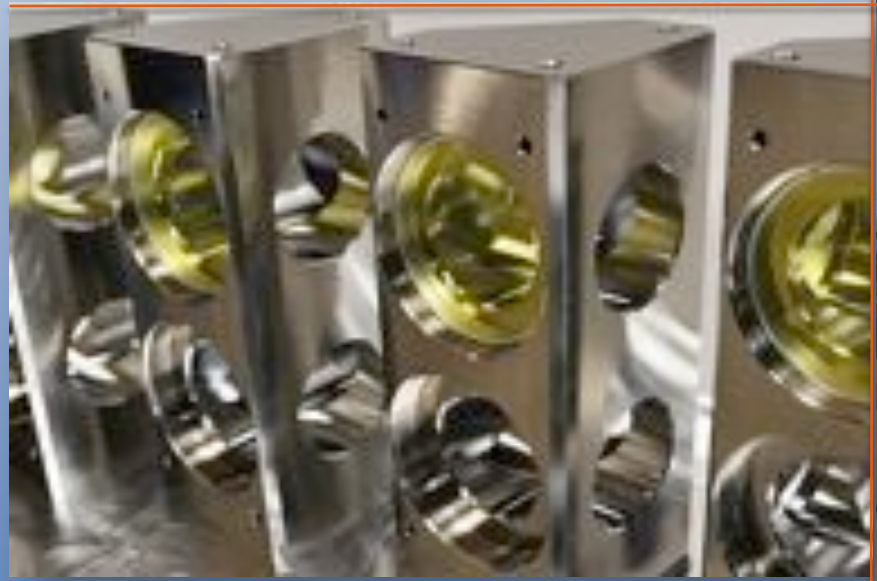
- Diagnostics
  - Transverse
  - Longitudinal
  - Charge, emittance, etc.
- RF structures
  - RF photoinjectors
  - Linacs, deflectors
- Magnetic systems
  - Electromagnets
  - Permanent magnets
  - Systems (chicanes, final focus, etc.)





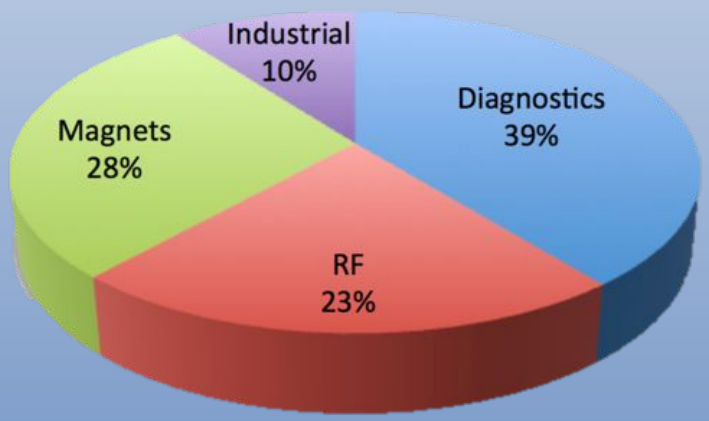
Production capabilities

- Prototyping and small scale production
- Testing, shipping, installation, support
- Turn key systems



Product development

- Wide customer base (50% of sales are international)
- Most products are custom or semi-custom
- Most sales are in small quantities

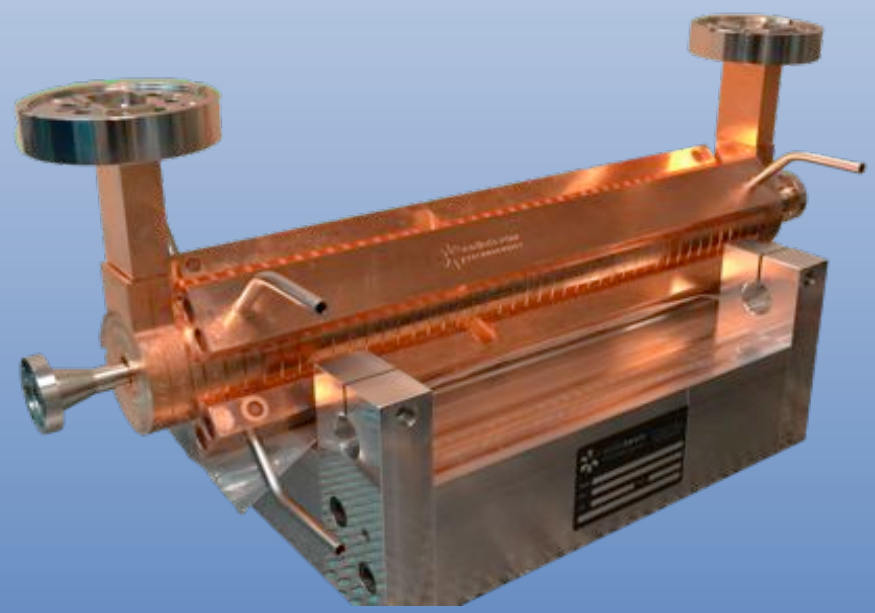


Non-competitive advantages

- EU (also Japan and Korea): institutionalized demand from domestic projects (labs delegate production to industry, unlike in US)
- China (also Russia): publicly subsidized production costs
- US: how to match international competition?
  - R&D funding (SBIR, BAAs, Stewardship)
  - Access to infrastructure (test facilities, specialized capabilities)
  - Access to expertise and tech-transfer (academia and national labs are encouraged to work with businesses)

X-band deflecting cavity

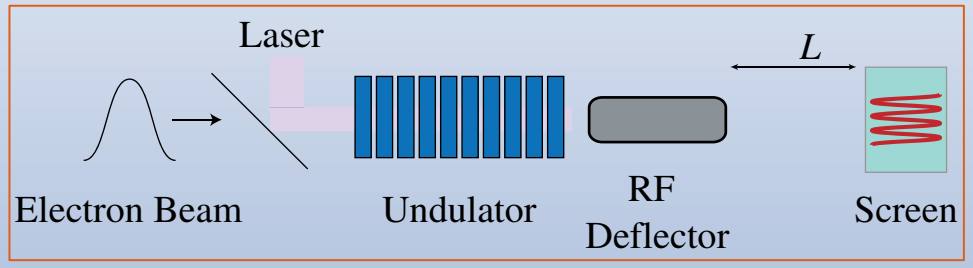
- X-band deflector (DOE SBIR grant 2007-2012)
  - Enables ~ 10 fs longitudinal resolution
  - Delivered completed structure to **ATF**
- Provided a major boost to RF capabilities at RBT
- Initiated a successful product line (i.e. PAL deflector)



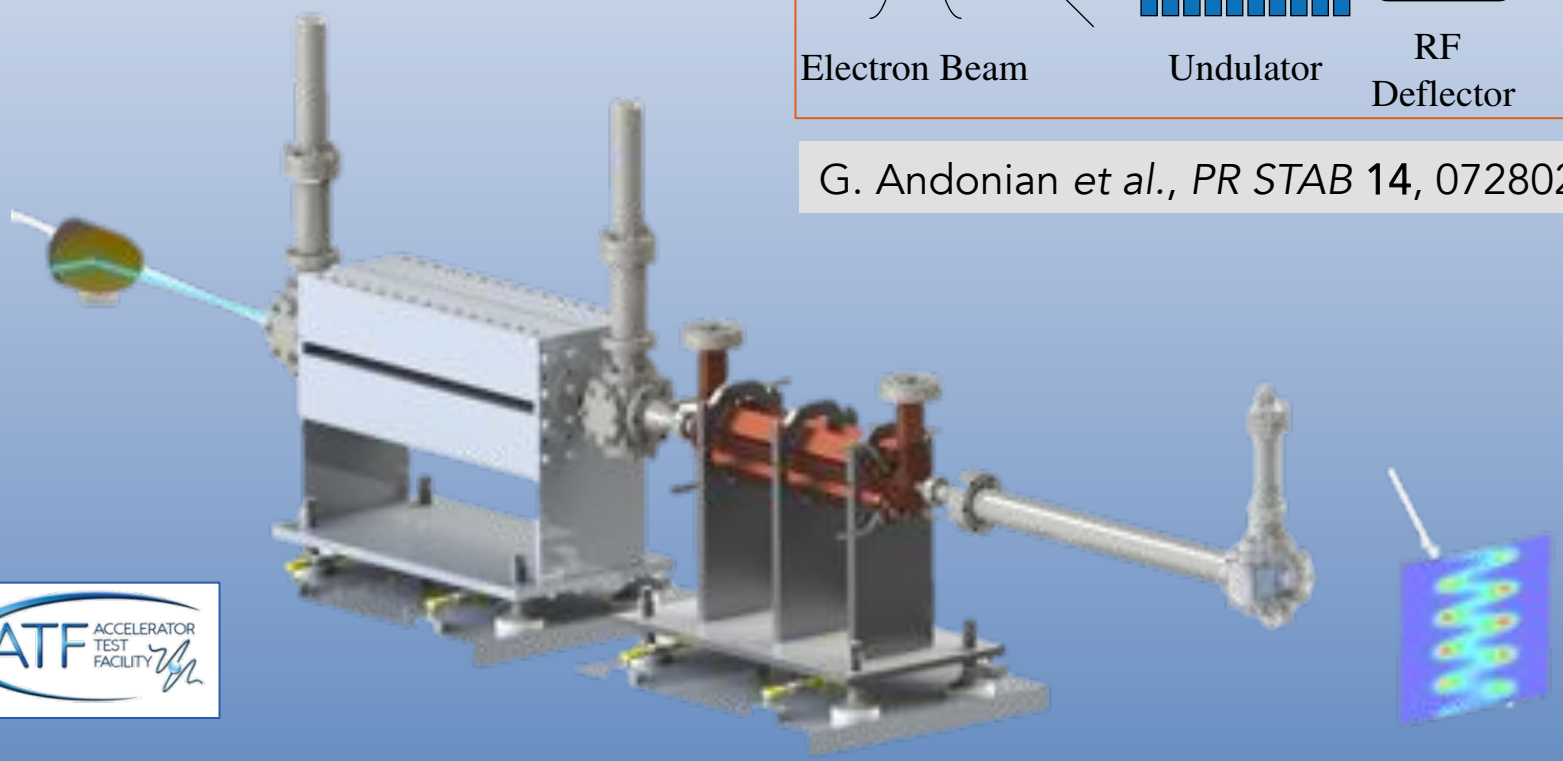
Commissioning at ATF is planned for 2015

Attoscope

- Enhancement to RF deflector (DOE SBIR)
- Laser/e-beam interaction
- Sub-fs resolution

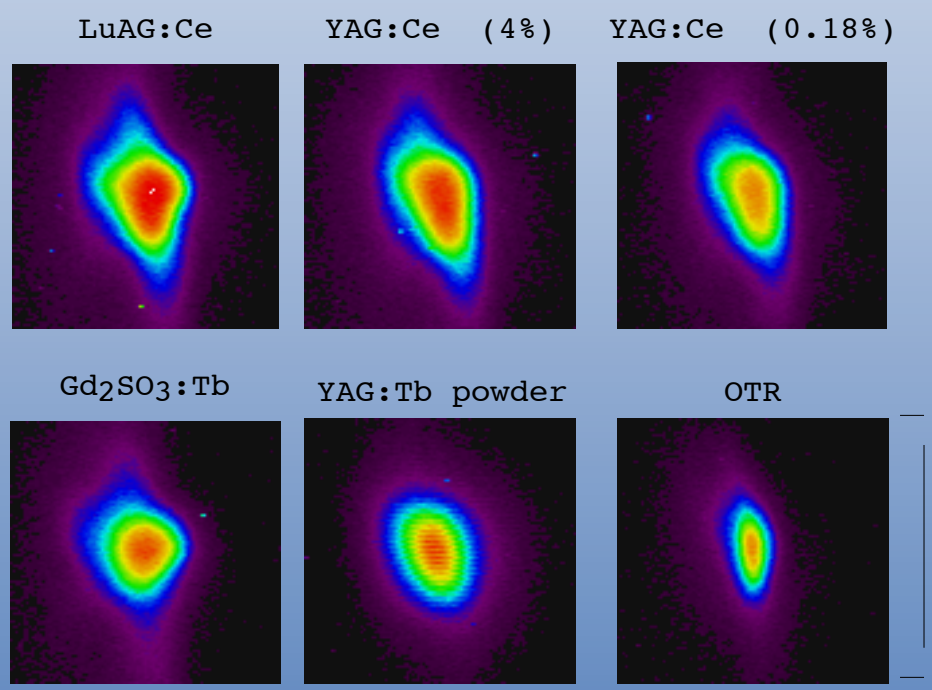


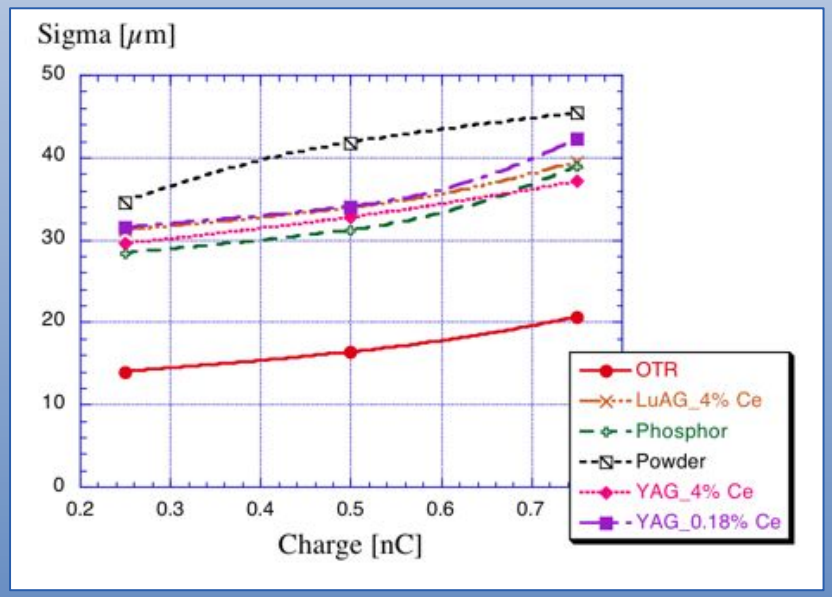
G. Andonian *et al.*, *PR STAB* **14**, 072802 (2011)



Beam profile diagnostics

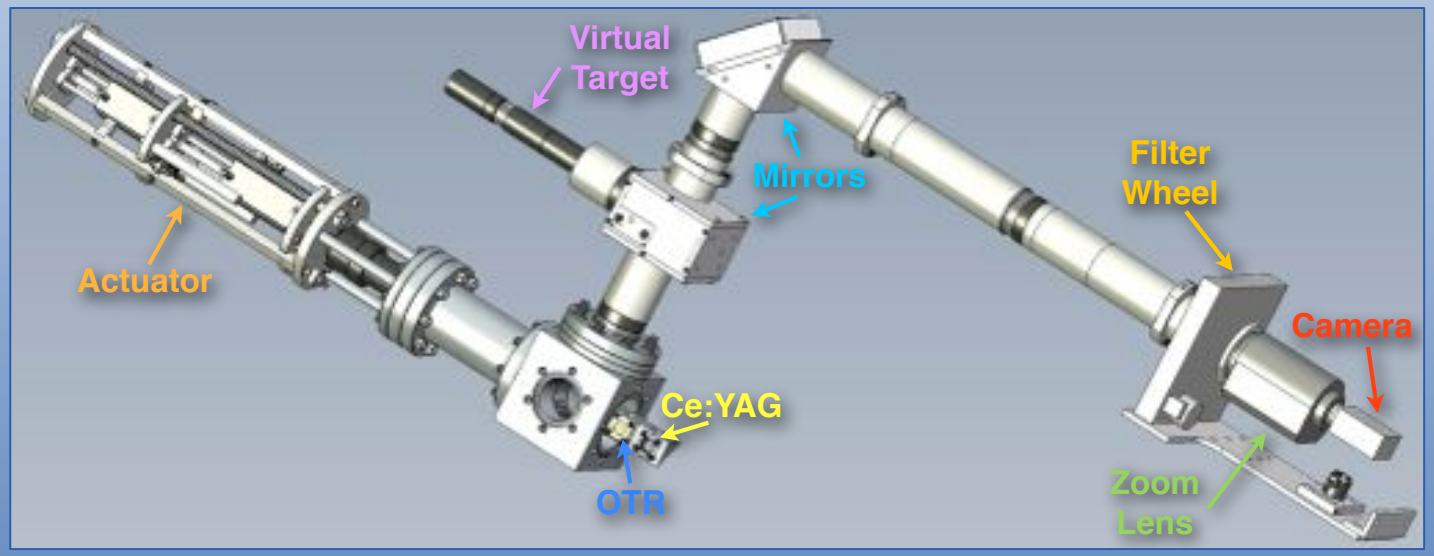
- **ATF** experiment demonstrated limitation of scintillators
- At higher beam densities OTR and wire scanner more accurate
- The best approach is to have multiple diagnostics available

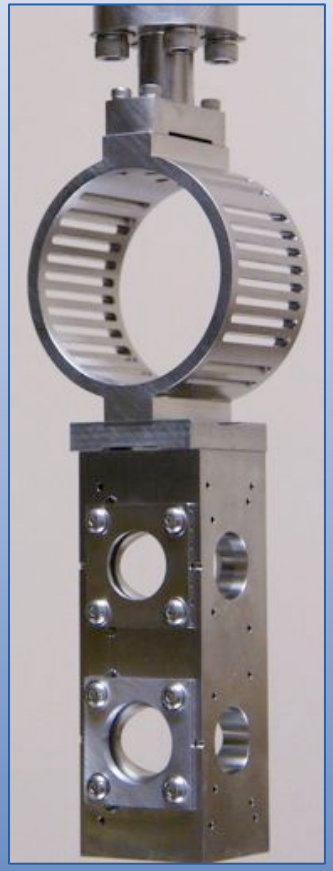




IBIS-2 (multi-position)

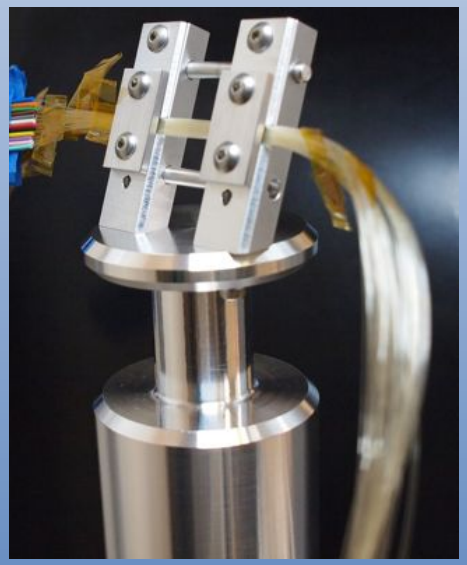
- Multi-position pneumatic actuator system
- Up to 4 diagnostics at the same port
- Modular system with multiple add-ons
- Since 2010, sold ~ 70 systems
- First 2 units tested at Fermilab and ATF

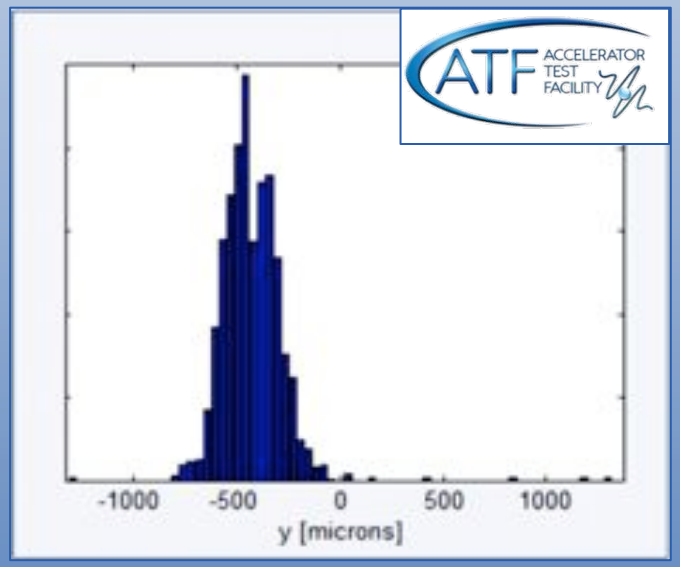


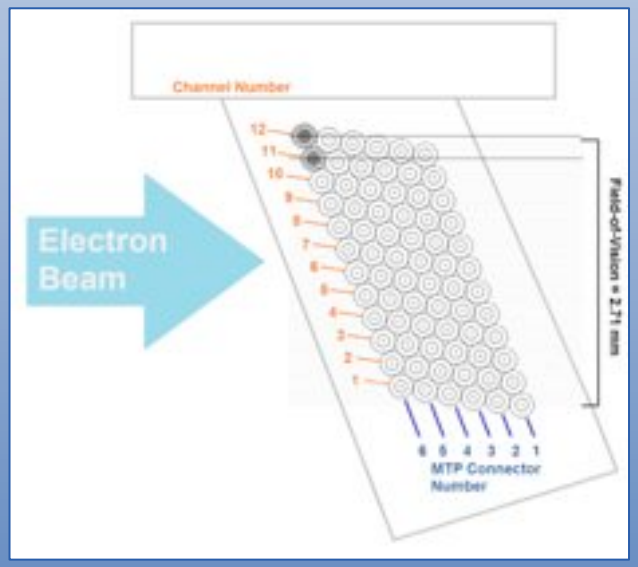


New developments

- COTR discovery introduced a new range of problems for transverse diagnostics at X-FELs
- Wire-scanners work well, but multi-shot
- Developed Cherenkov single-shot “wire scanner” based on fiber mesh (DOE SBIR 2010)

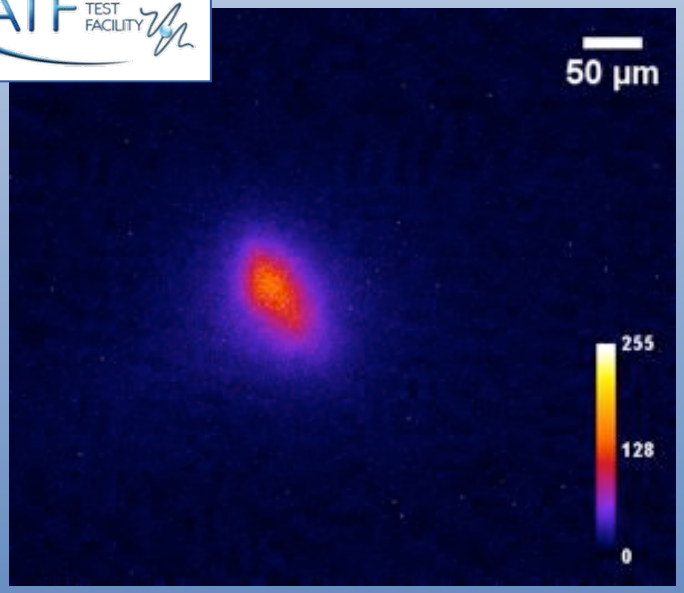


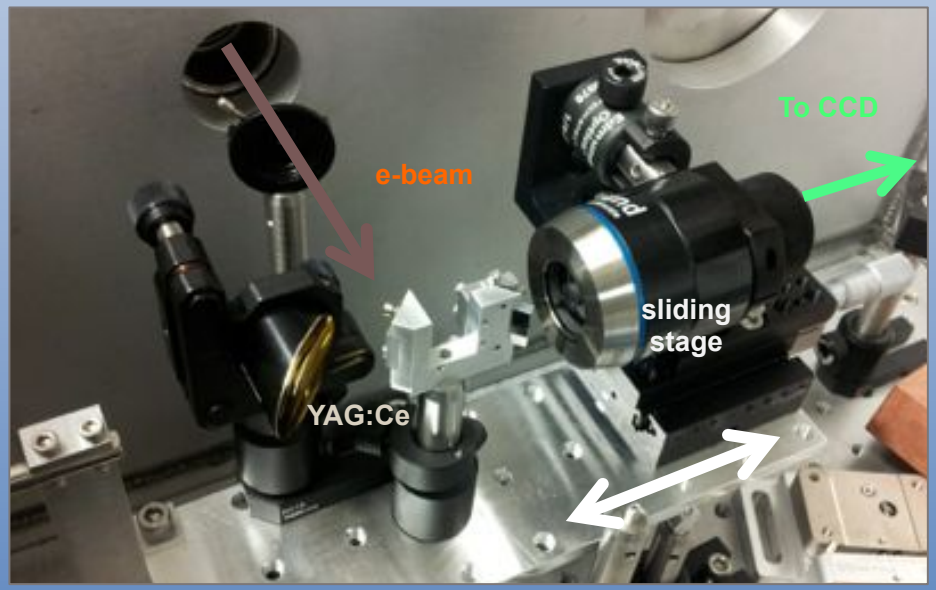




New developments

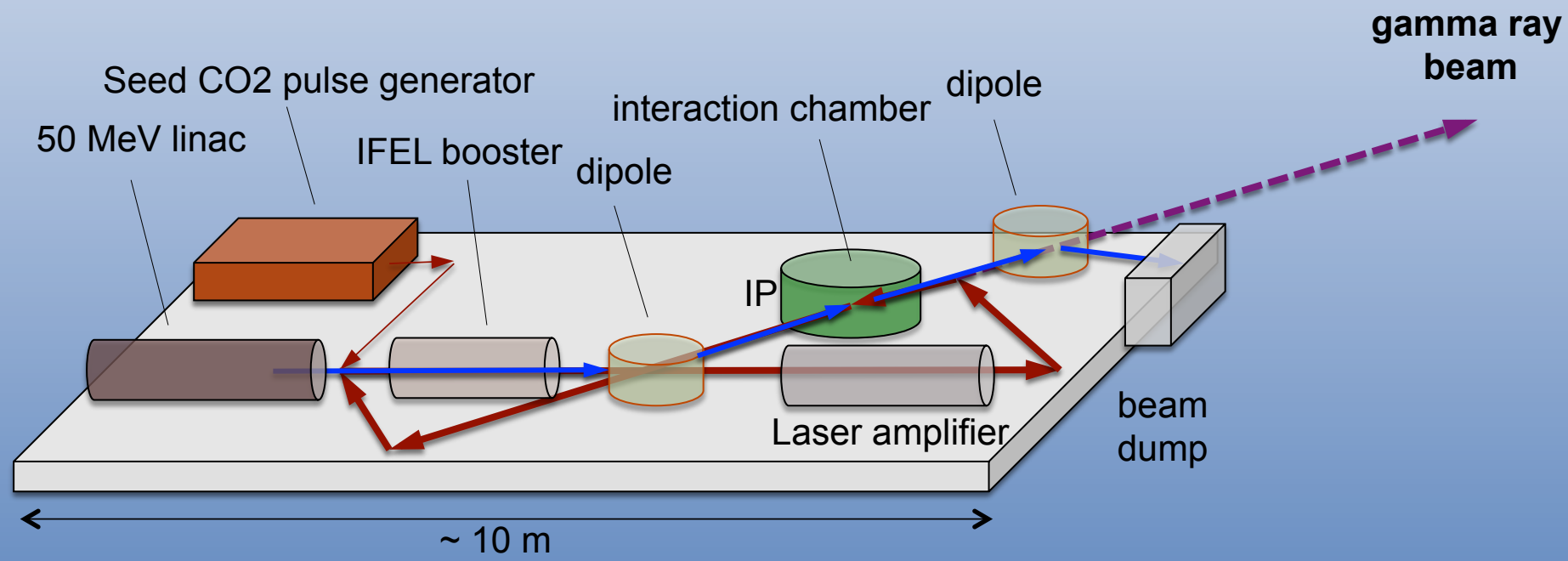
- Dielectric Laser Accelerators, although in infancy, require sub-micron diagnostic resolution
- Developed reflective DUV OTR diagnostics
- Initial tests at **ATF** indicated 0.5 μm resolution





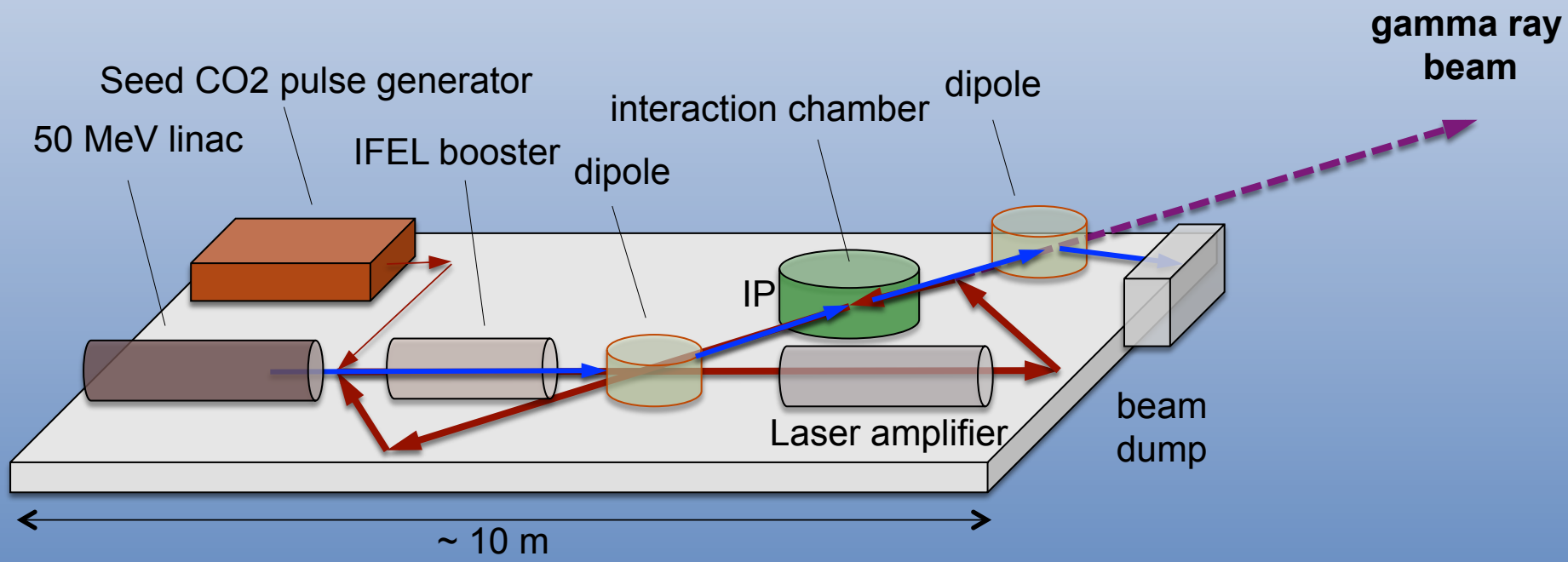
STINGRay

- **S**ource of **T**unable, **I**ntense, **N**arrow-bandwidth **G**amma **Ray**s (compact, high rep. rate)
- IFEL uses same laser as ICS (1-10 MeV, 10^{13} cps)
- Modular funding approach (starting 2008)



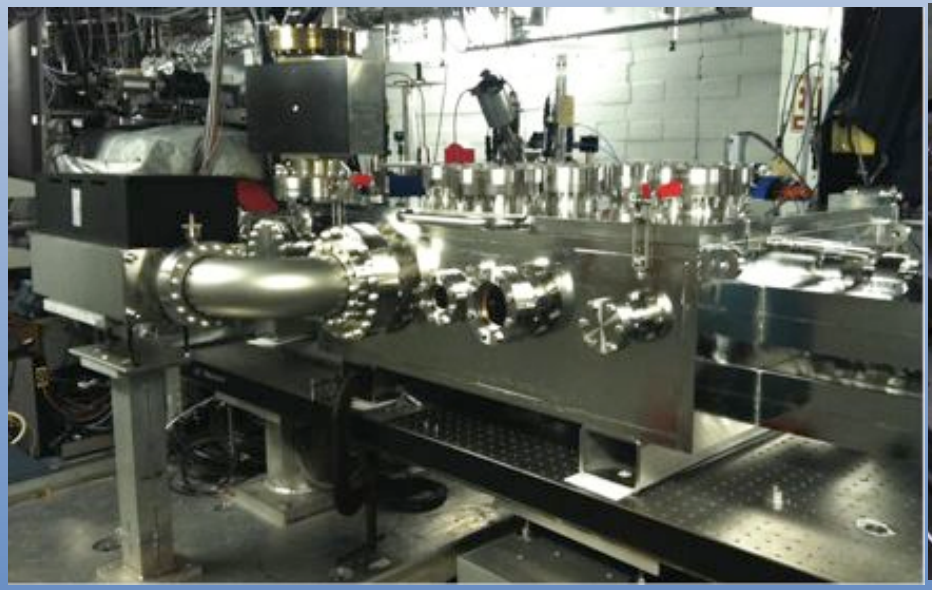
STINGRay

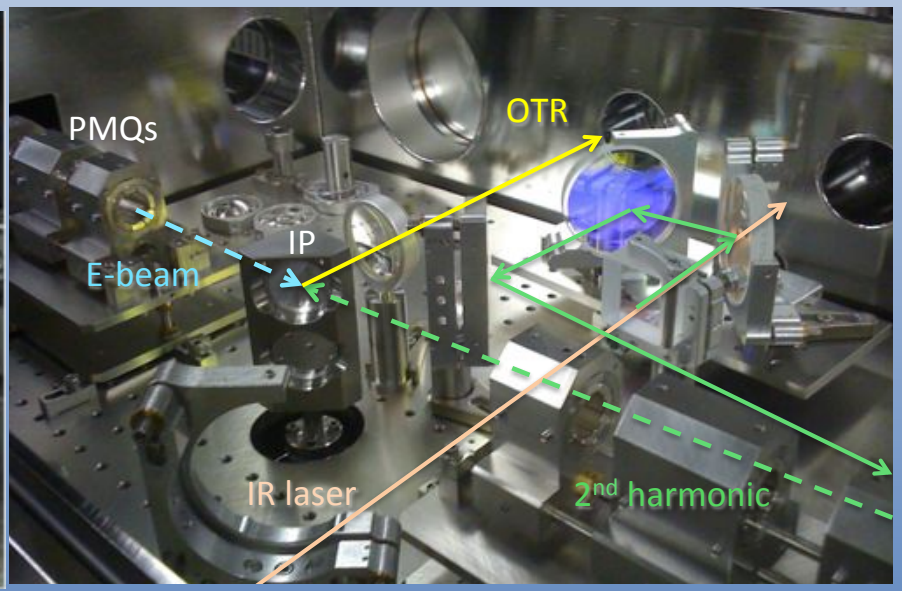
- Demonstrated: **IFEL**, **high efficiency ICS**, **laser recirculation**
- Future work: high gradient IFEL, recirculated ICS, ICS+IFEL, complete stand-alone system



1st ICS experiment

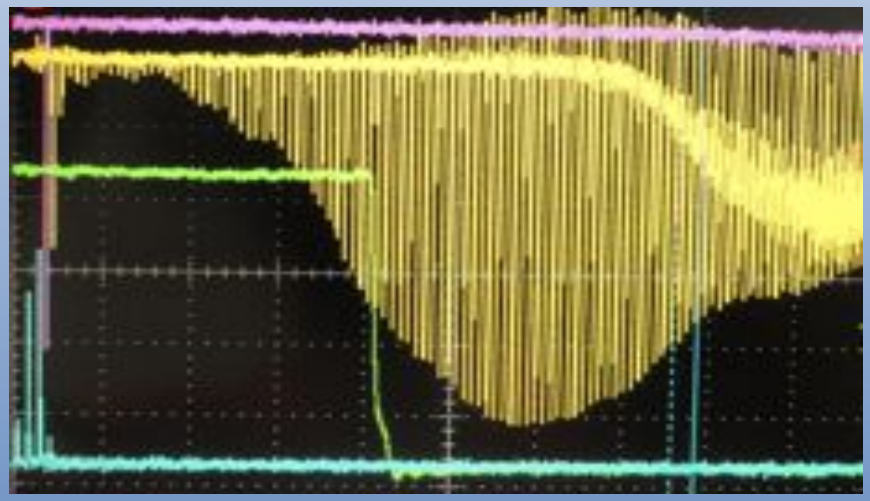
- DTRA SBIR (2009)
- Recirculated 530 nm laser (RING cavity)
- Conducted a pilot experiment at **ATF**
- Mixed results, a lot of learning experience

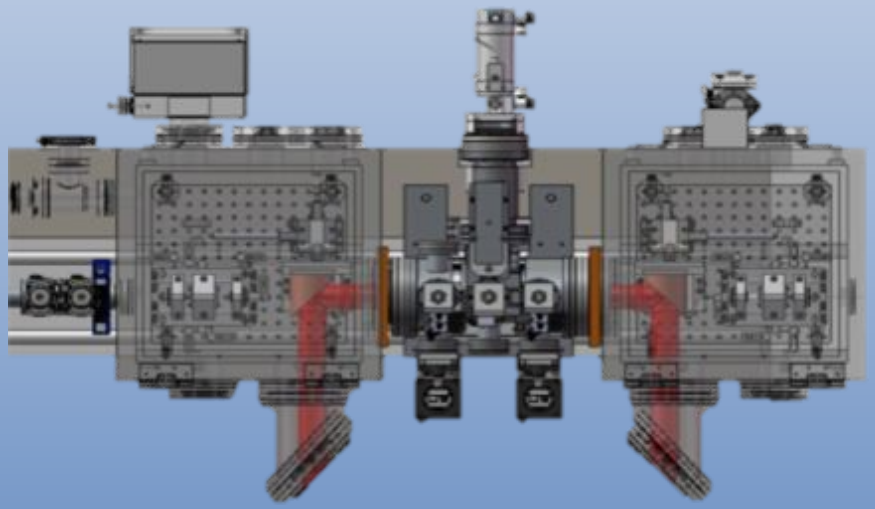




Active cavity (@ 10 μm)

- DOE SBIR (2013)
- Obtained 30 J pulse-train at 40 MHz (Dec. 2013)
- Strong integration with the **ATF** program
- Pulse train ICS is planned for early 2015





Conclusion

- Accelerator Test Facility plays a crucial role to help US small businesses to invent, develop and test new products
- ATF is an ideal host facility for long term multi-institutional programs, which eventually can bring disruptive innovations to the market
- ATF is a part of the publicly funded infrastructure, which makes US businesses more competitive internationally
- **Wish list for ATF-2:**
  1. streamlined procedure for quick experiments
  2. more space: floor / bench top / shielded / office