The Micro Accelerator Platform: A Potential Injector for a DLA Based Collider

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Abstract

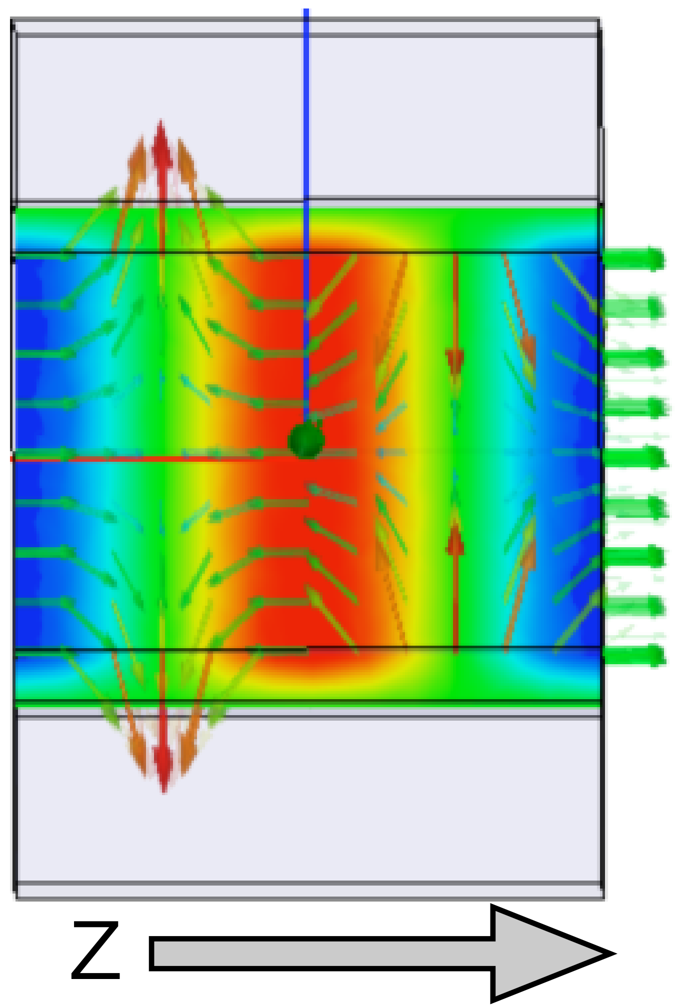
- The application of advanced accelerator techniques to high energy colliders places demands on the injector system that may be best addressed with advanced injector technologies. With Dielectric Laser Accelerators, the transverse and longitudinal bunch profile as well as the repetition rate required are ill suited for production in conventional injectors. In plasma based schemes, it is often suggested to use plasma based injectors. This talk will discuss the possibility of using a modified DLA--the Micro Accelerator Platform (MAP)--as an injector to a DLA. The MAP is a slab-symmetric laser-powered structure. The MAP is being studied as a sub-relativistic device with an integrated electron gun. There are many challenges in making the MAP, or any DLA, suitable for low-beta acceleration. This talk will very briefly outline some of these challenges, attempts to address them, and what advantages such an effort might have for a future collider.

What is the MAP?

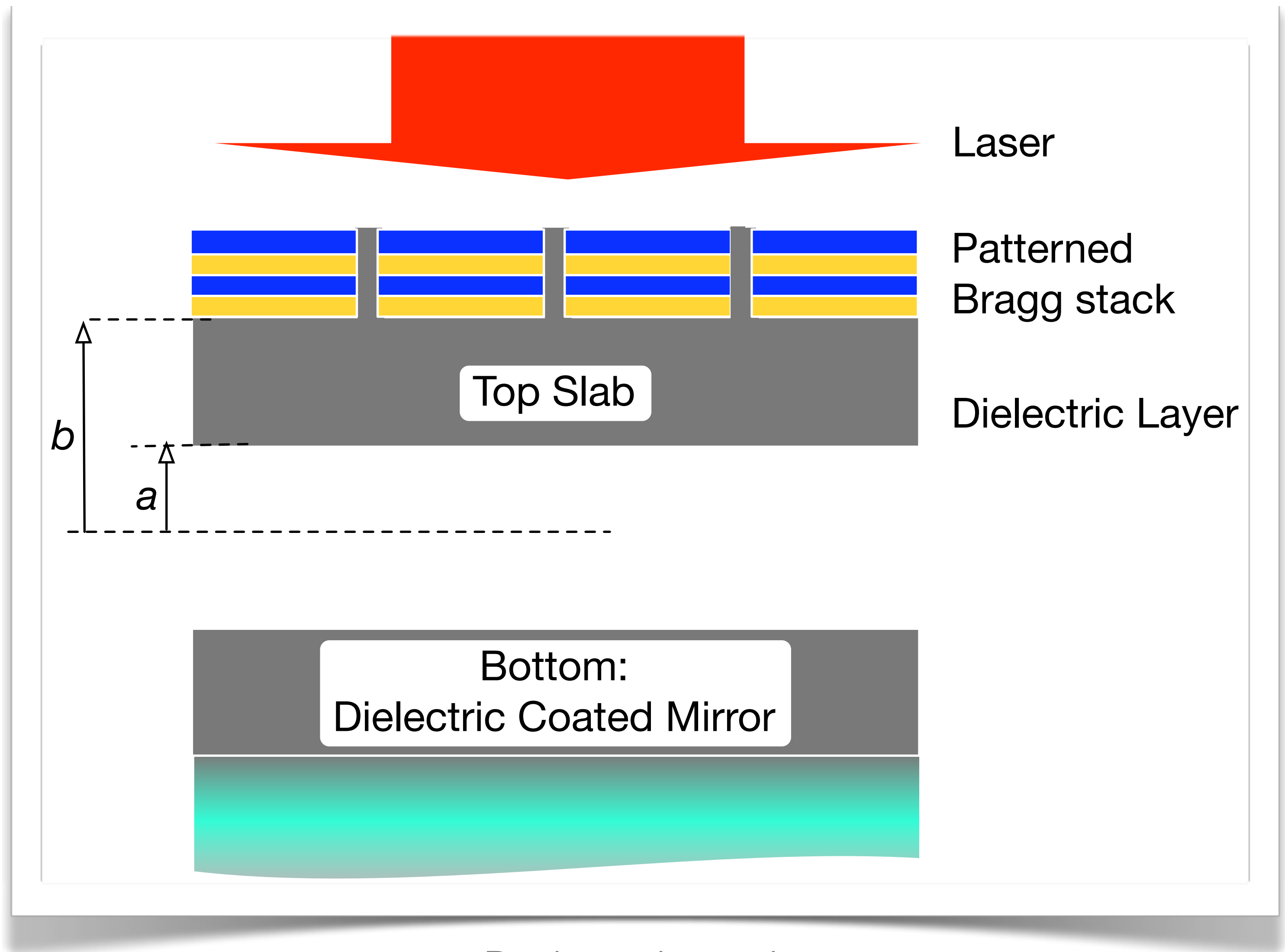
At UCLA, we are designing, fabricating and testing a slab-symmetric, laser-driven, dielectric micro accelerator

Periodic modulation in z is necessary to have an accelerating mode: a standing wave with $k_z = \omega/\beta c$.

resonant structure with good E_z fields



one period

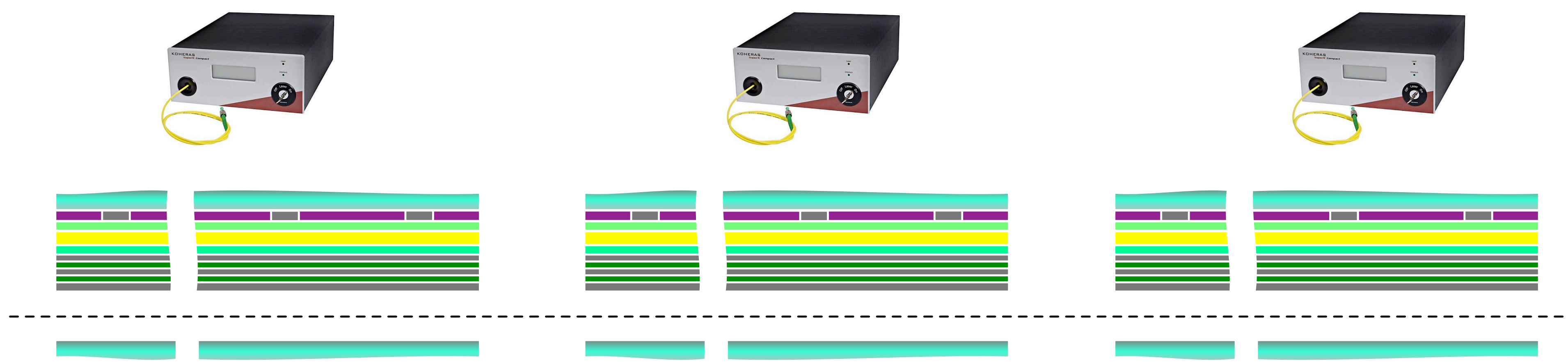


Device schematic;
structure variation in *x* not shown
Typical values (λ=1μm)
a ~ 1 μm
b-a ~ 10 nm
number of periods ~ 1000
overall length ~ 1 mm

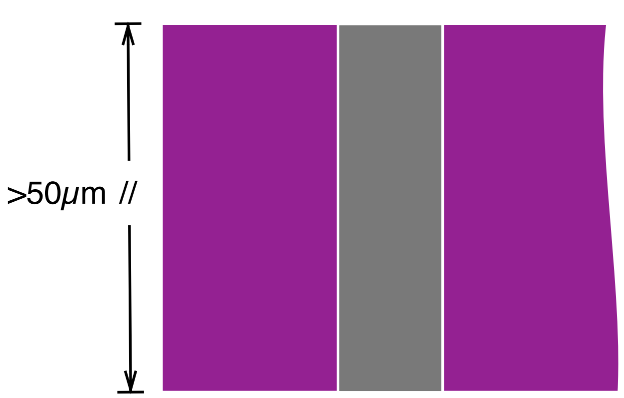
The Micro Accelerator Platform (MAP) offers a number of collider friendly features

easy power coupling

“easy” to scale & stage

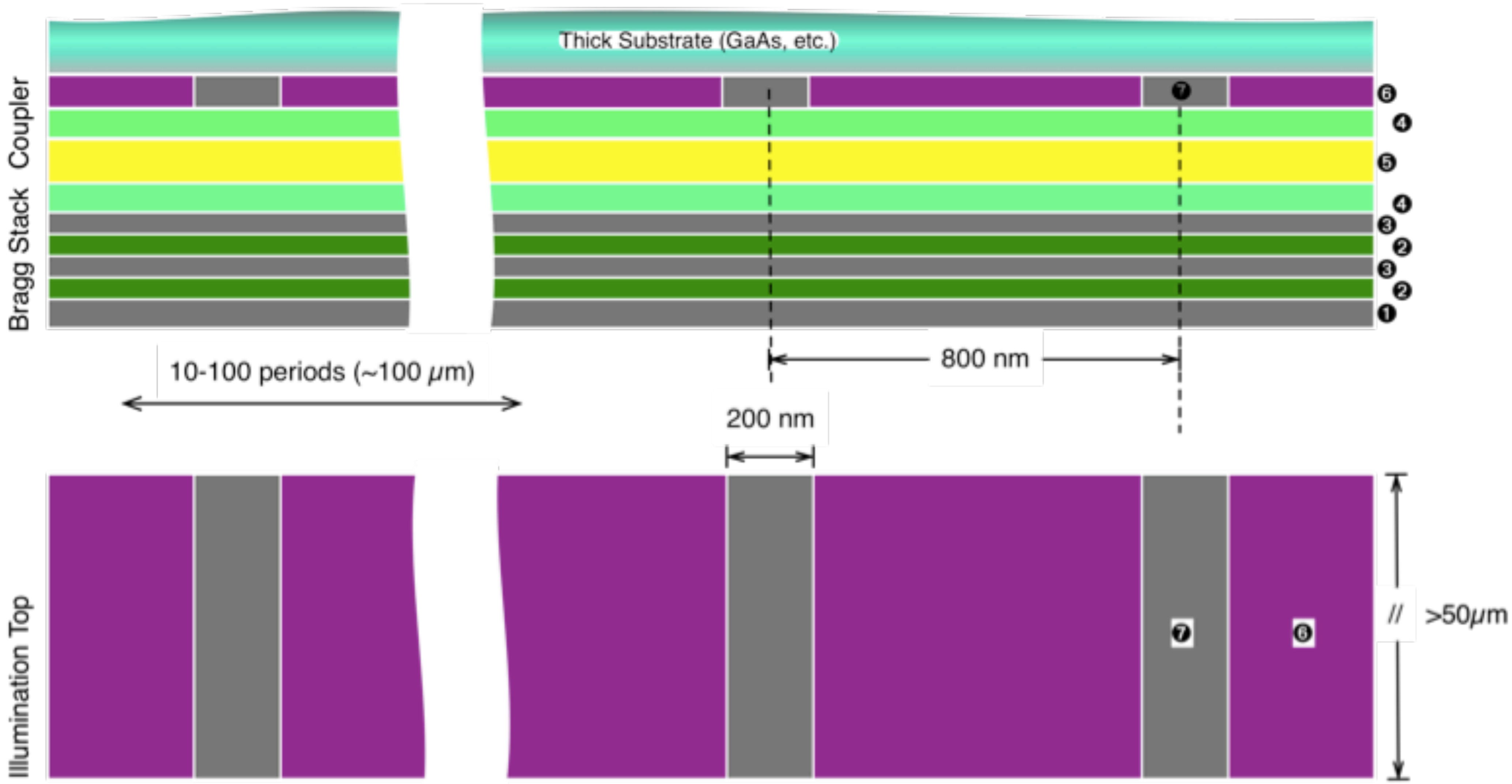


flat beams
low wakefields



What about breakdown, Gil!?

The structure consists of a diffractive optic coupling structure and a partial reflector



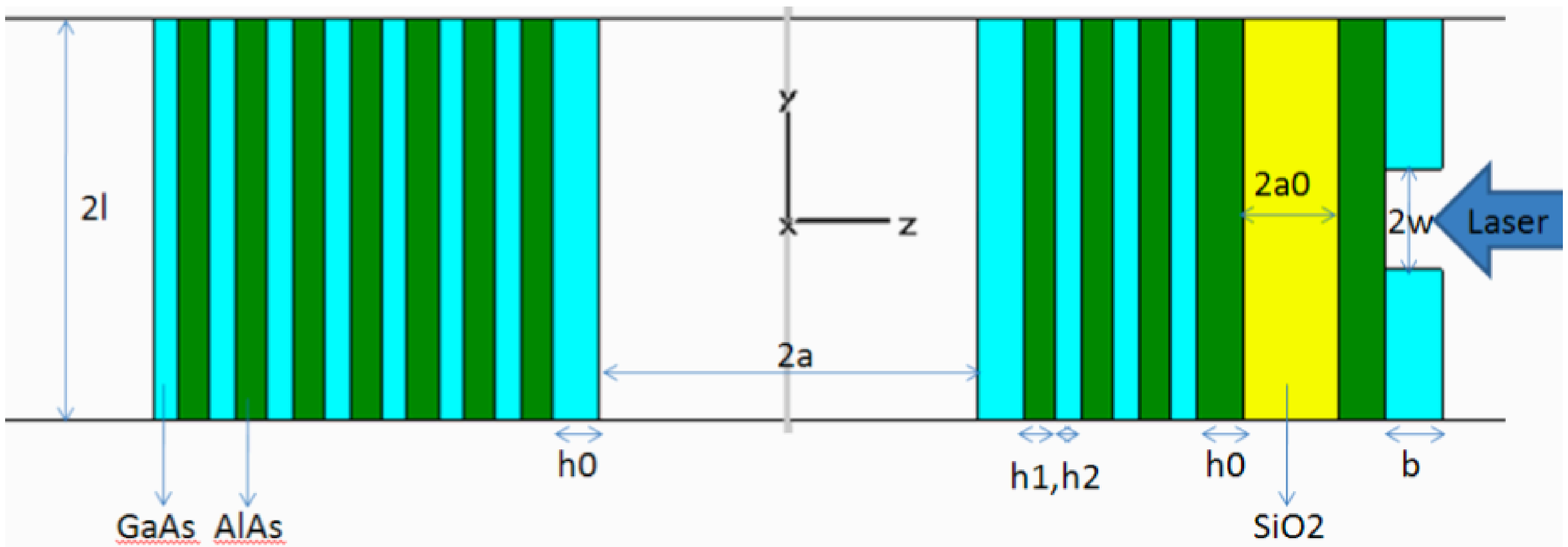
Ideal **field profile** in gap: $E_z = E_0 \cosh\left(\frac{k_z y}{\gamma}\right)\cos(k_z z)$

where $k_z = \omega / \beta c$ varies with electron velocity

Resonance condition:
(*a* and/or *b* vary along structure)

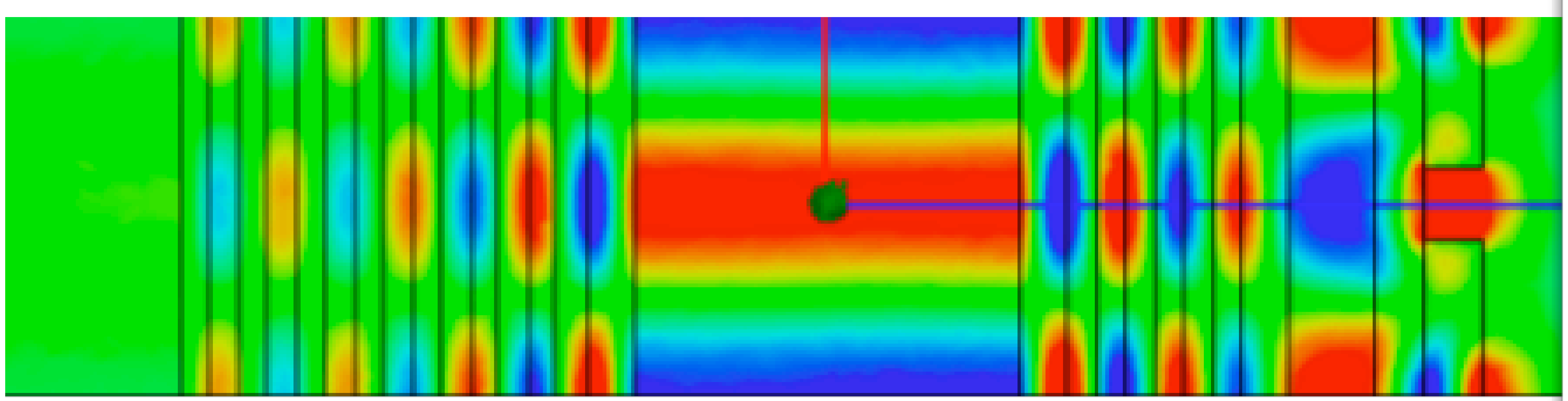
$$\frac{\gamma\beta}{\varepsilon}\sqrt{\varepsilon-(1/\beta)^2} = \coth\left(\frac{k_z a}{\gamma}\right)\cot\left[\sqrt{\varepsilon-(1/\beta)^2}\,\frac{\omega}{c}(b-a)\right]$$

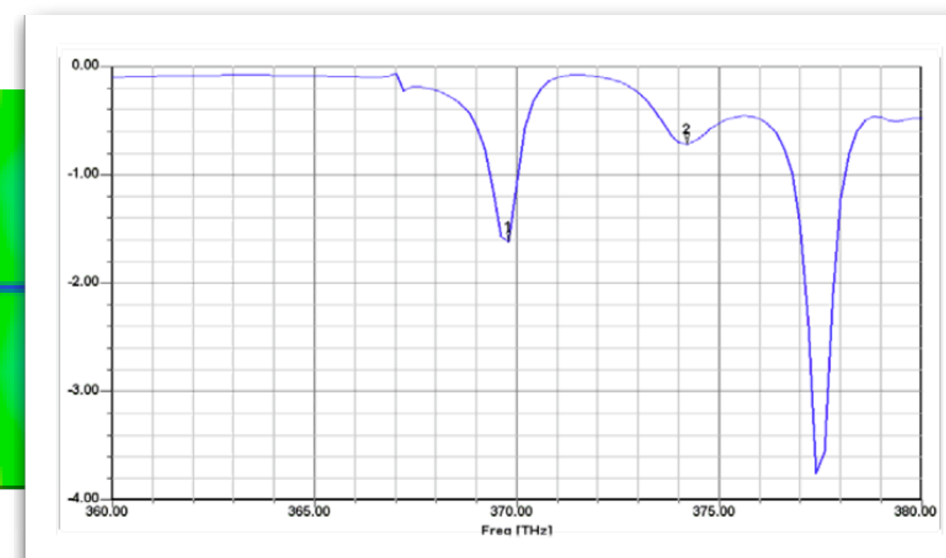
We have a preliminary design of the all-dielectric structure.



Coupling structure on top of Bragg reflector etalon.

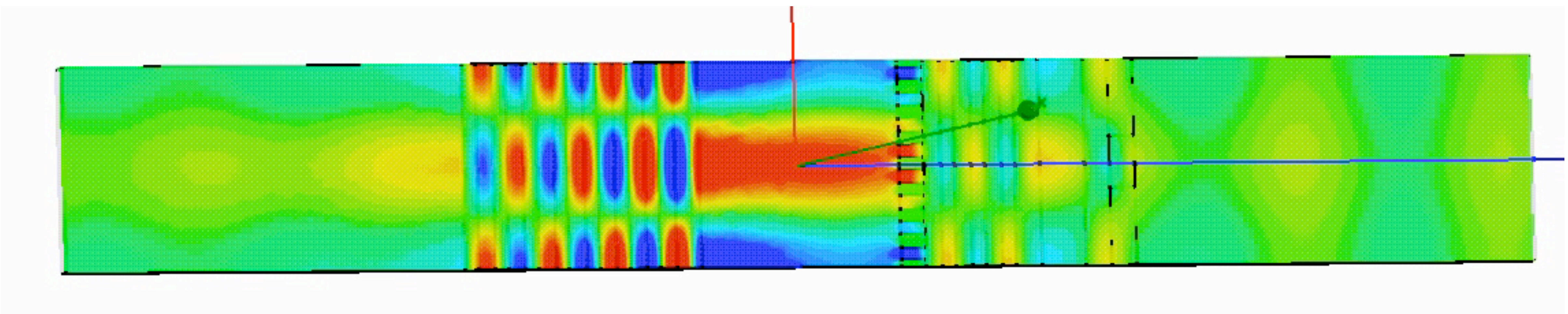
Periodicity and coupling in one structure element.





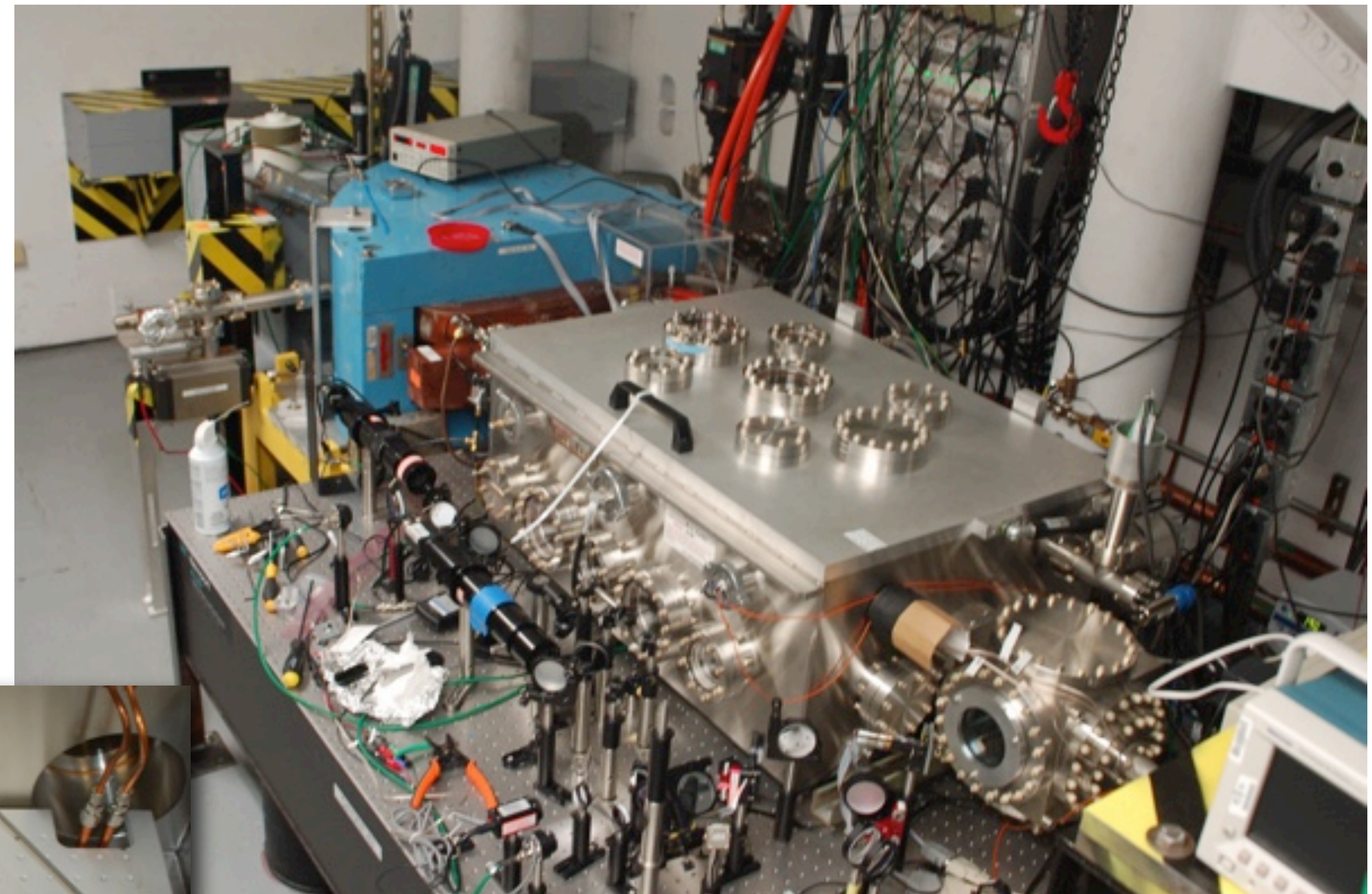
We still have a lot of work to do on the ß<1 structure

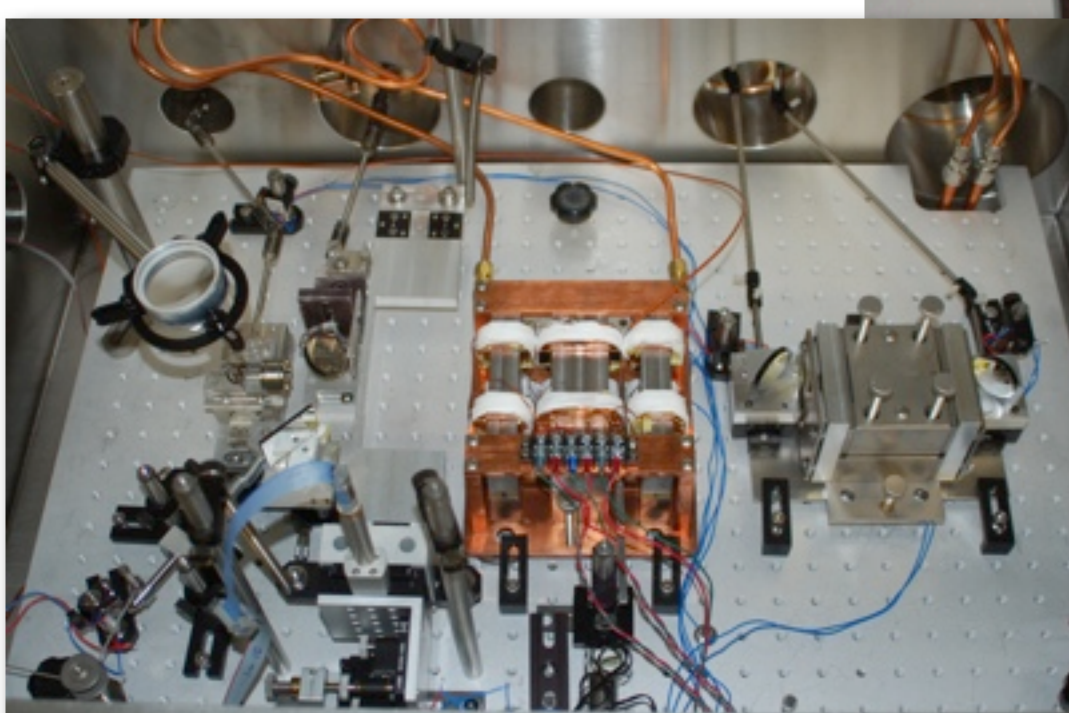
The E_z field quality is sensitive to the details of the coupler, Bragg stack and inner geometry



Beam testing is planned at SLAC's E163 facility which hosts a suite of micro accelerator tools.

AARD





radiabeam TECHNOLOGIES

SLAC NATIONAL ACCELERATOR LABORATORY

PBPL

How can we produce a low-beta structure?

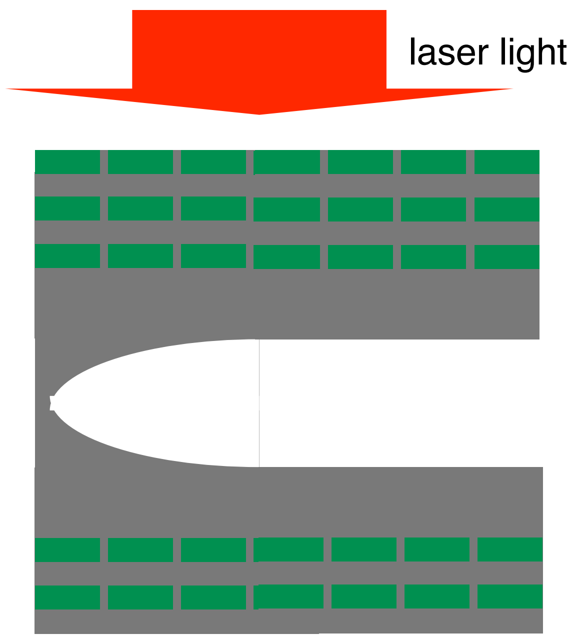
at 1 GeV/m, each period only produces 1KeV

1000 periods only yields 1 MeV

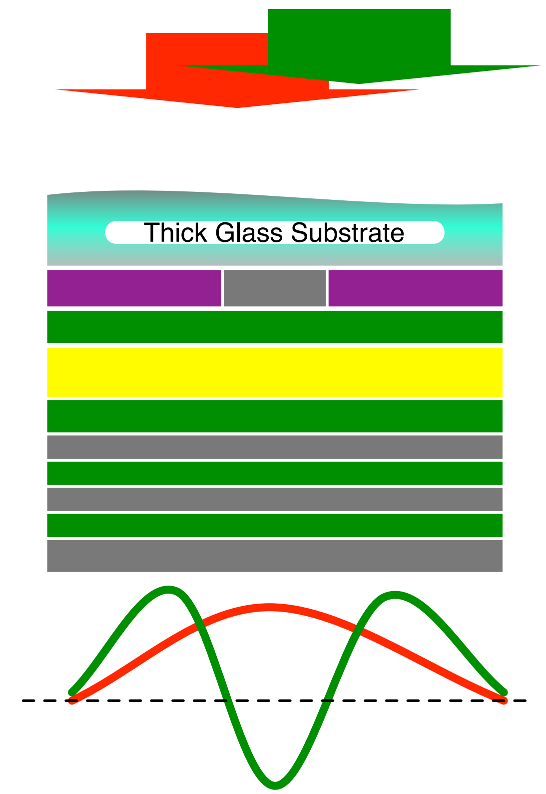
1 TeV requires 1 billion periods

Creating a sub-relativistic MAP is hard: the coupling and periodicity are one and the same

tapered structure



two-color operation

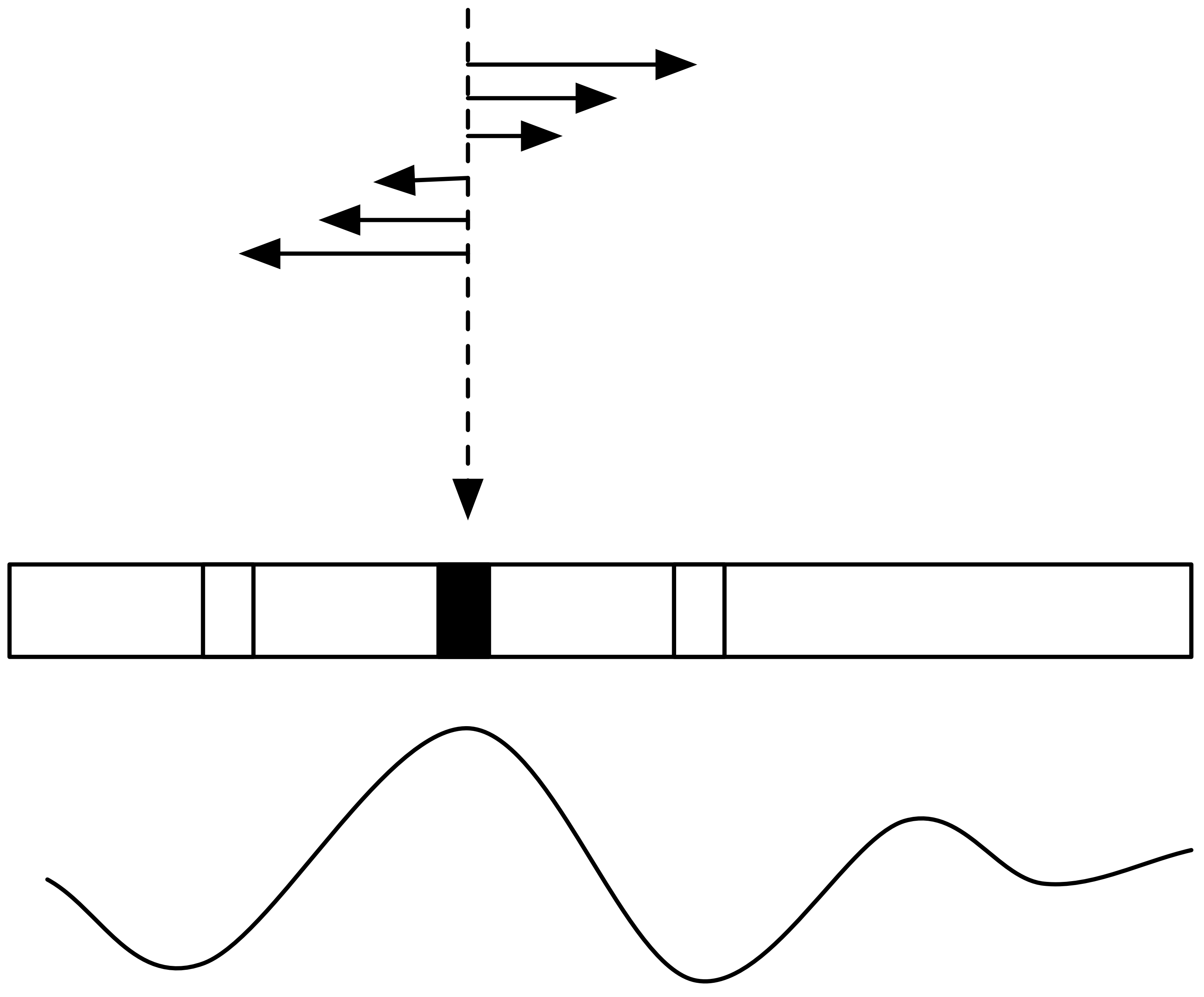


periodicity variation

periodicity skipping

DTL-like

An aperiodic coupling may allow for net acceleration at $v<c$



The accelerating field may die off before the particle full dephases

Ming Xie proposed alternating gradient acceleration for laser accelerators (~1998)

$$\Delta W_a = qE_aL_aT_a$$ **is the energy gain**

$$\Delta W_d = qE_dL_dT_d$$ **is the energy loss**

Net energy gain...

$$G_{2\pi} = \frac{\Delta W_a + \Delta W_d}{L_a + L_d} > 0$$

and this implies...

$$\frac{E_d}{E_a}\frac{L_d}{L_a}\frac{T_d}{T_a} < 1$$

$$\frac{d\gamma}{dz} = -ka\cos\psi$$

$$\psi = \omega t - \int_0^z k_z(s)ds$$

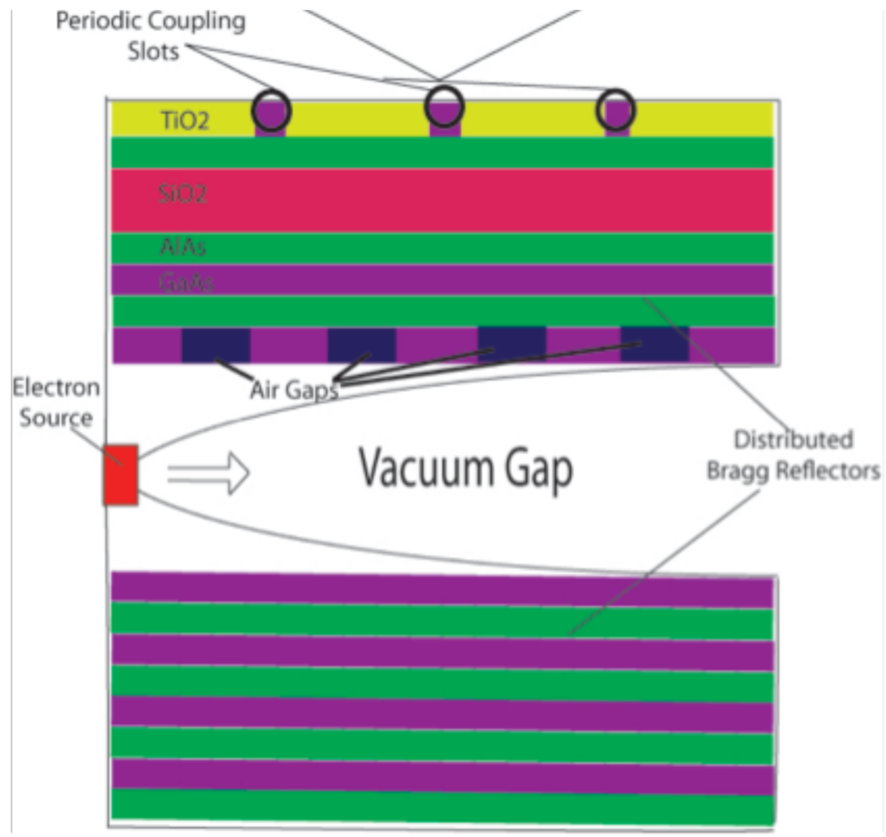
$$a = \frac{eE(z)\lambda}{2\pi mc^2}$$

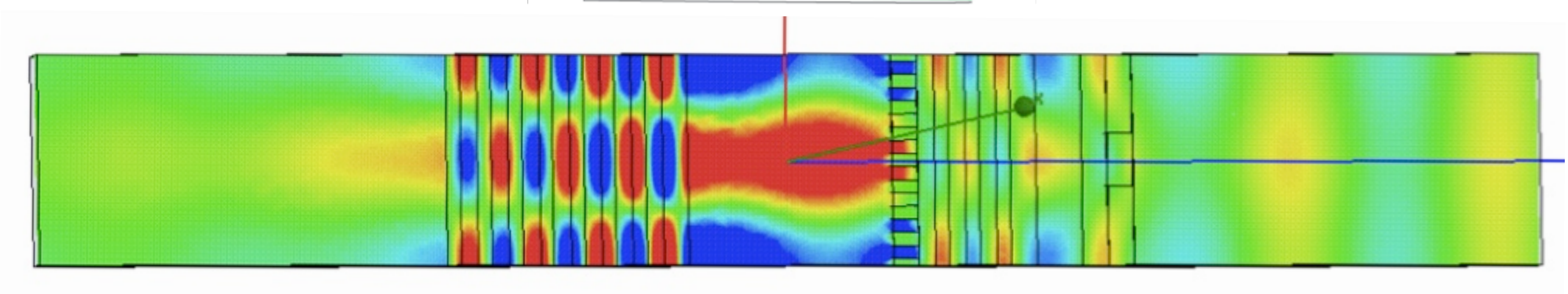
⋮

$$\frac{d\overline{\gamma}}{dz} = ka_sS_l\sin\psi_\gamma$$

The dielectric “matching” layer can help to provide good fields over a narrow range

As only certain values of dielectric constants are available, we examined alternating two materials, including vacuum gaps.





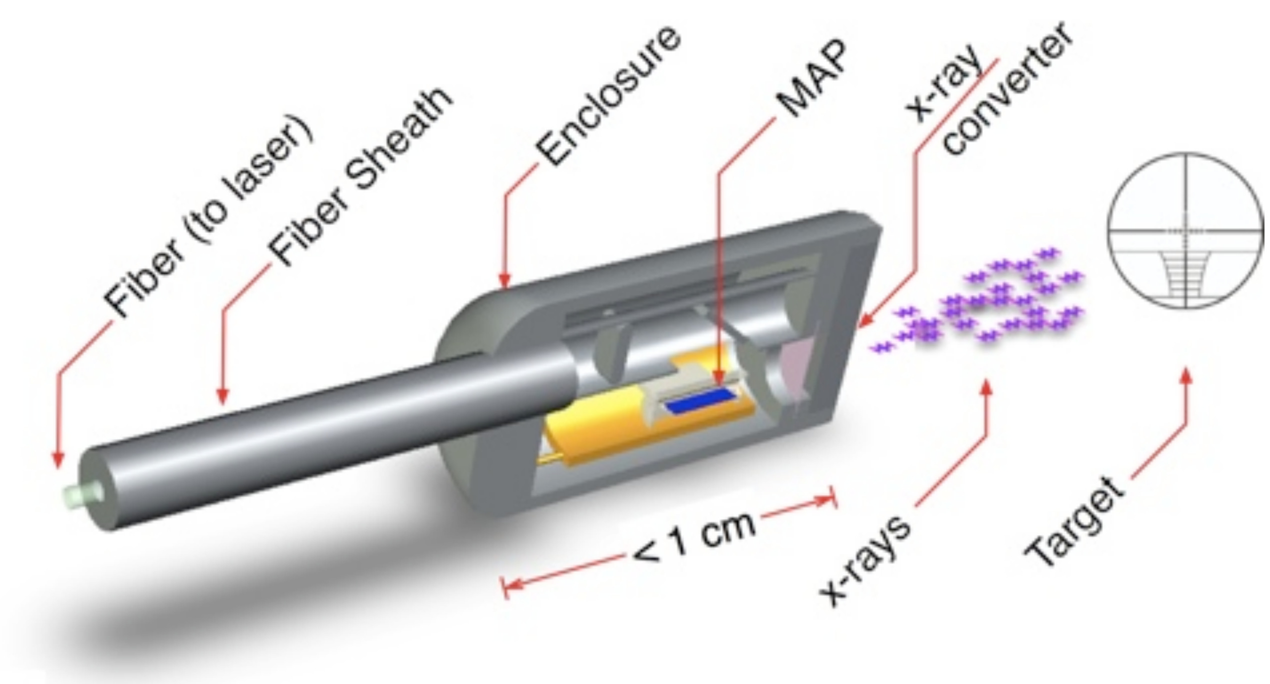
The MAP as a DLA-based collider injector

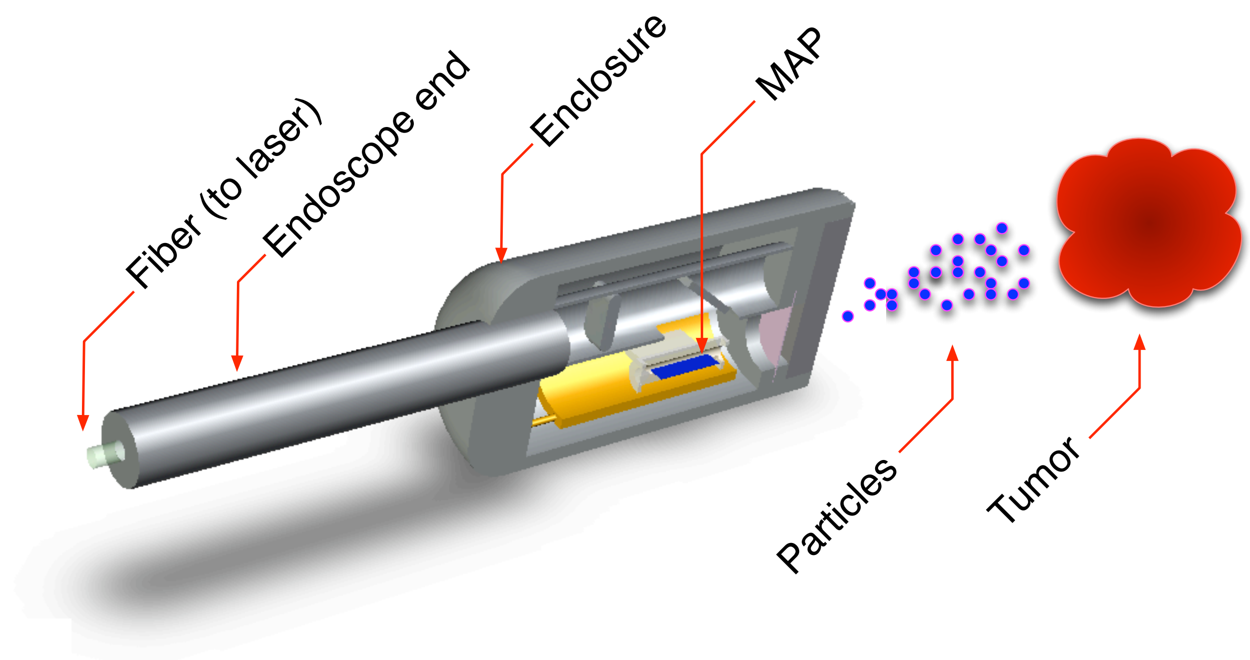
The nominal DLA-based collider parameters match well to a MAP-based injector

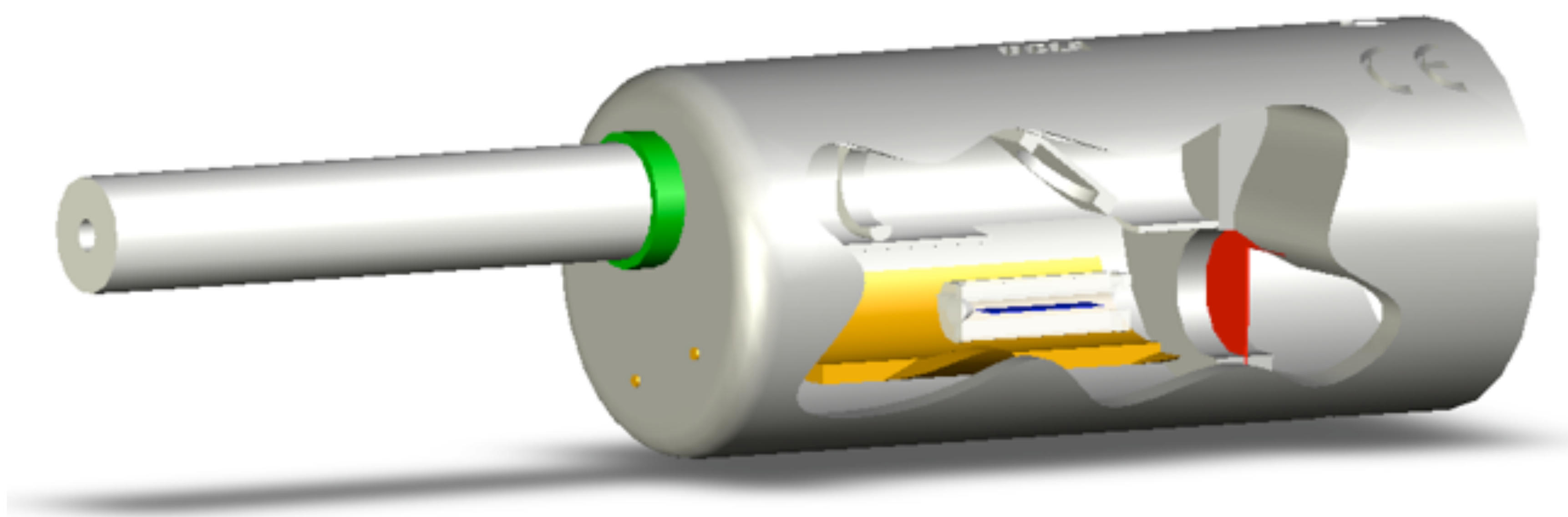
		ILC Nom.	Grating
E_cms	GeV	1000	1000
Bunch Charge	e	2.00E+10	**1.00E+04**
# bunches/train	#	2820	**375**
train repetition rate	MHz	5.00E-06	**20**
final bunch length	psec	1.00	**1**
design wavelength	micron	230609.58	**0.8**
Invariant Emittances	micron	10/0.04	**1e-04/1e-04**
I. P. Spot Size	nm	554/3.5	0.5/0.5
Enh Lumi/ top1%	**/cm^2/s**	**4.34E+34**	**4.58E+34**
Beam Power	MW	22.6	6.0
Wall-Plug Power	MW	104.0	120.1
Gradient	MeV/m	30	830
Total Linac Length	km	33.3	1.2

E. Colby (SLAC)

The development of a MAP-based collider injector is consistent with other long term goals





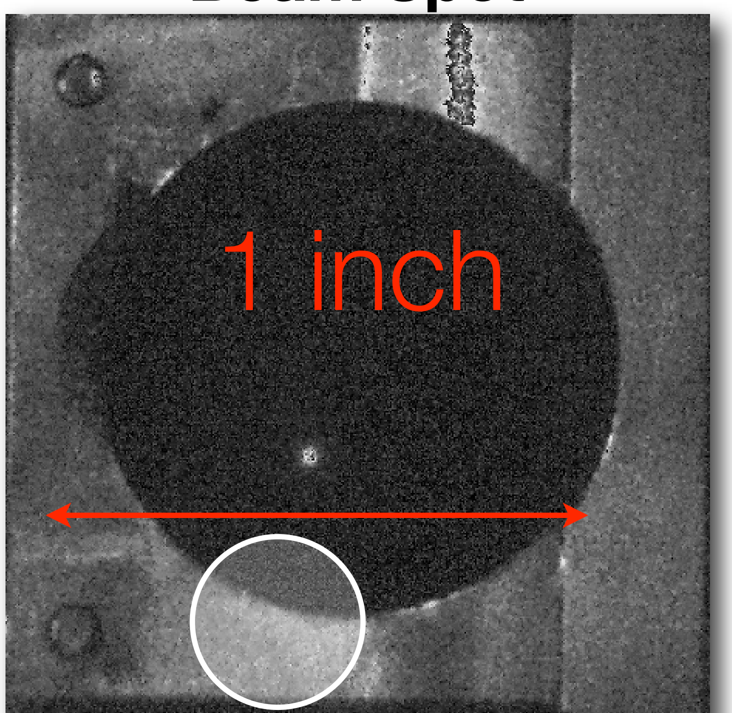


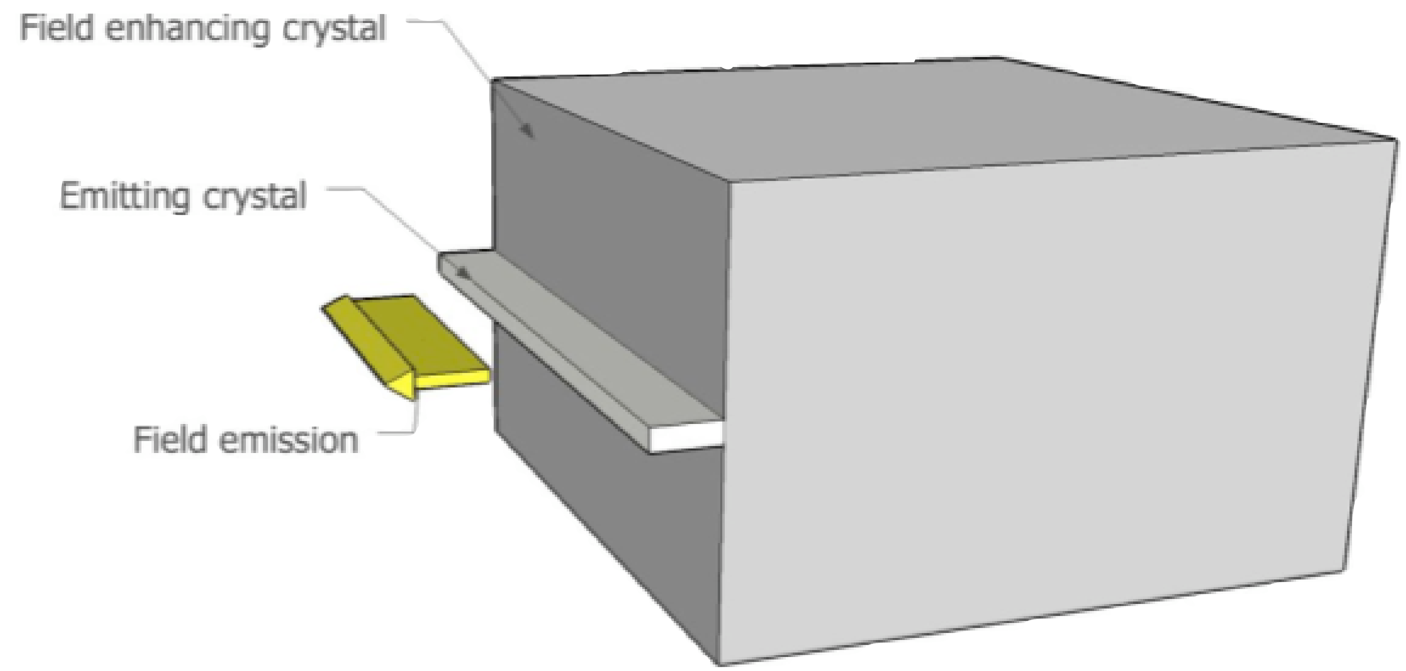
The particle source

An integrated gun may solve the beam injection problem and enable micro self-contained sources.

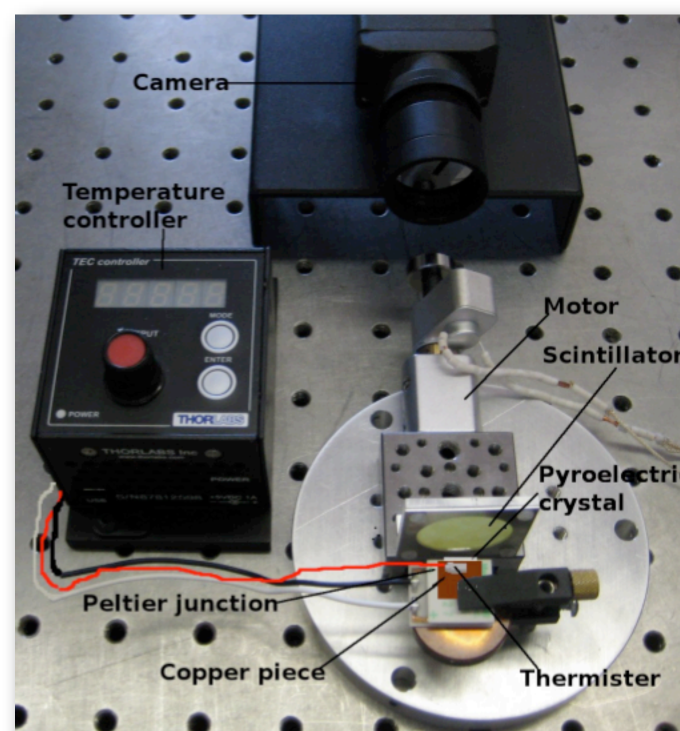
We have obtained emission from a 300μm Li:Nb wafer.

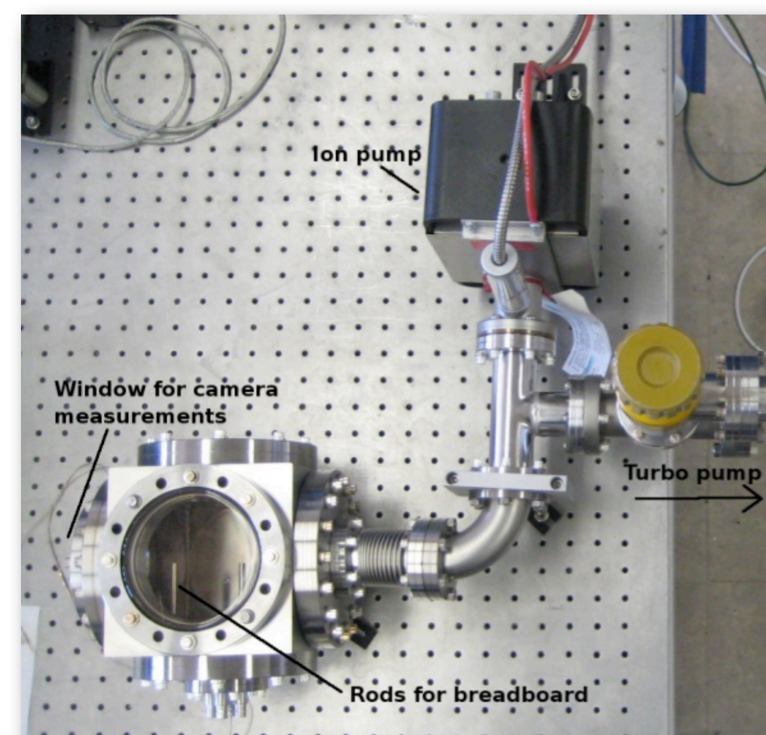
Beam Spot





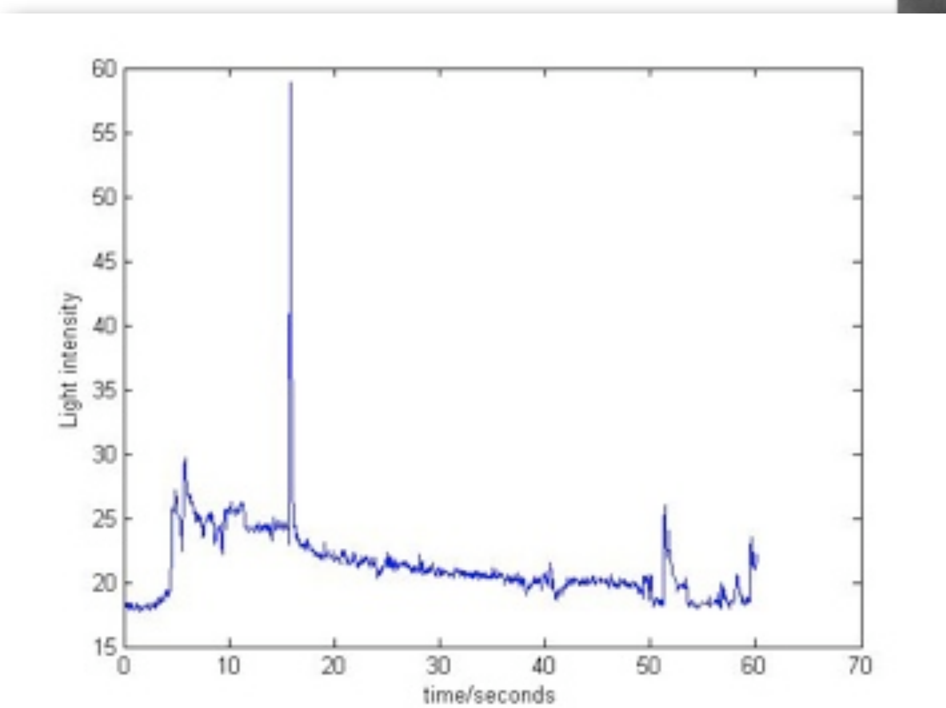
test stand for piezo/pyro electric materials.

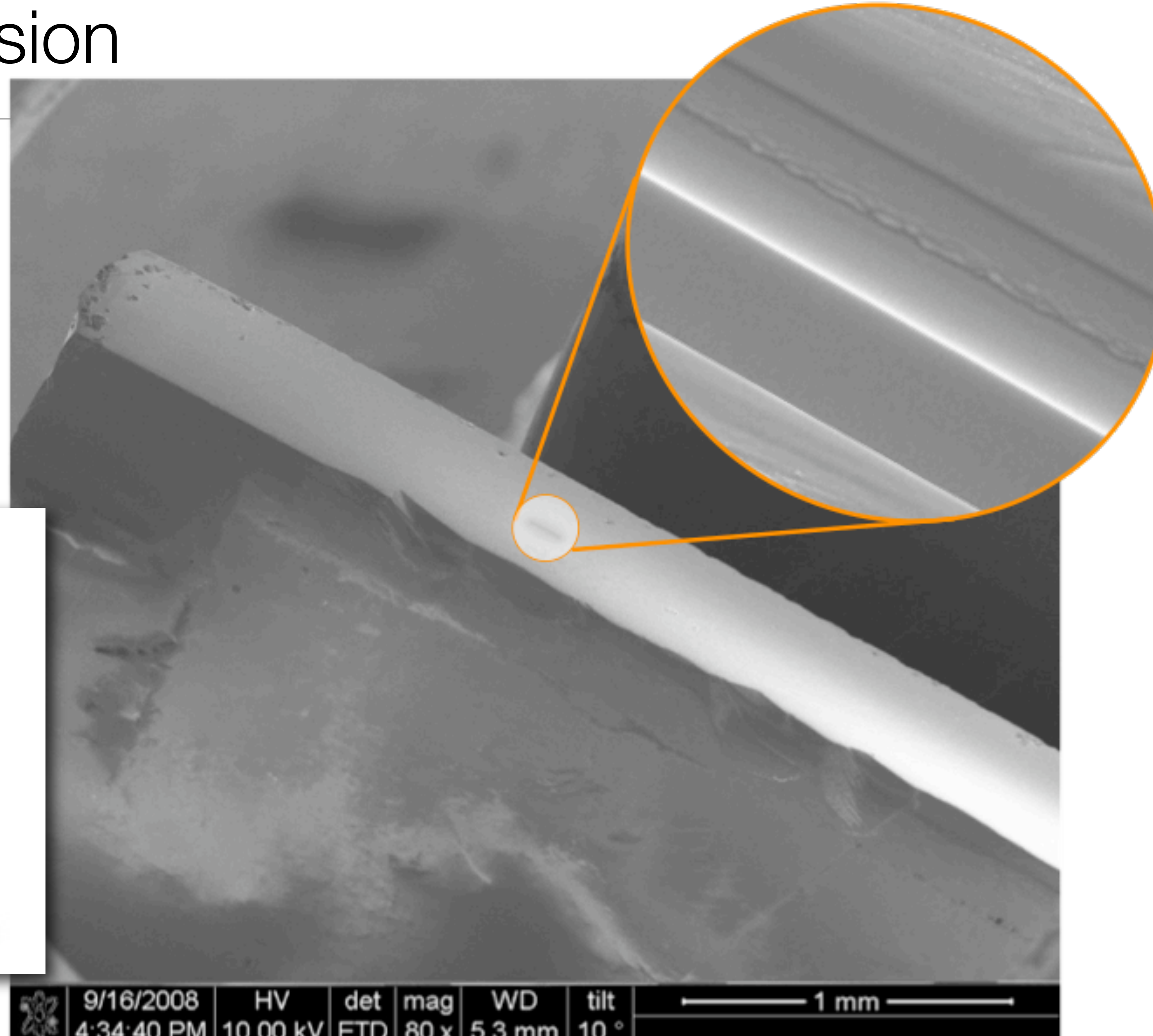




The micro patterned crystal produces quasi-continuous emission

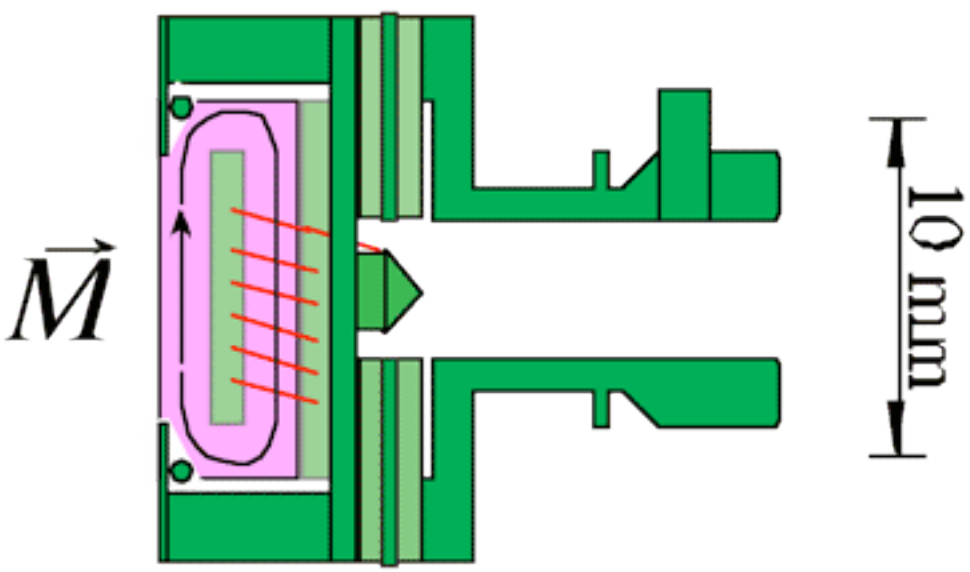
Emission vs. Time

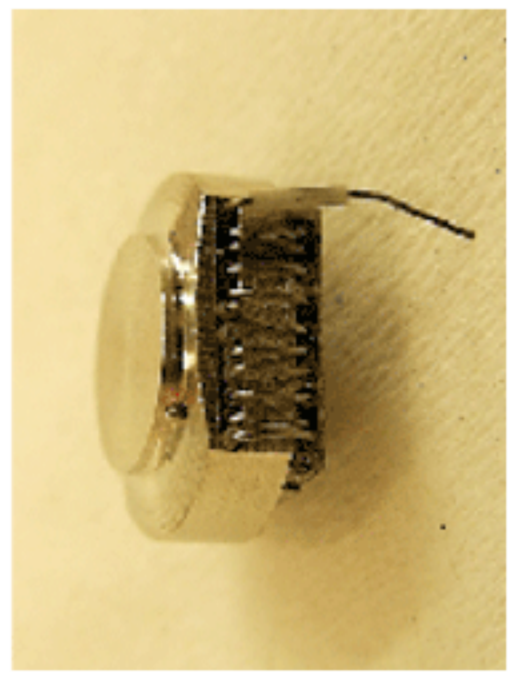




Can polarized electrons be produced?

hexagonal boron nitride (ferroelectric) coated cathode





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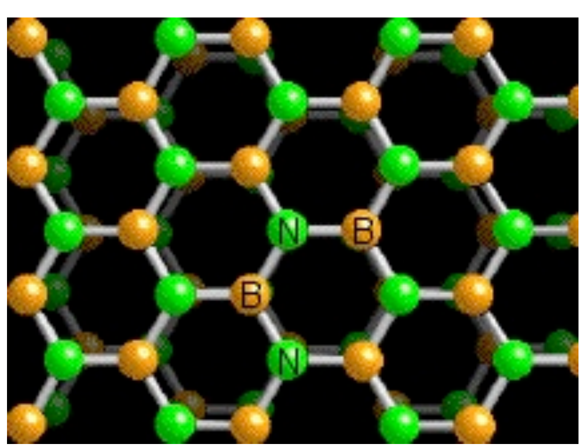

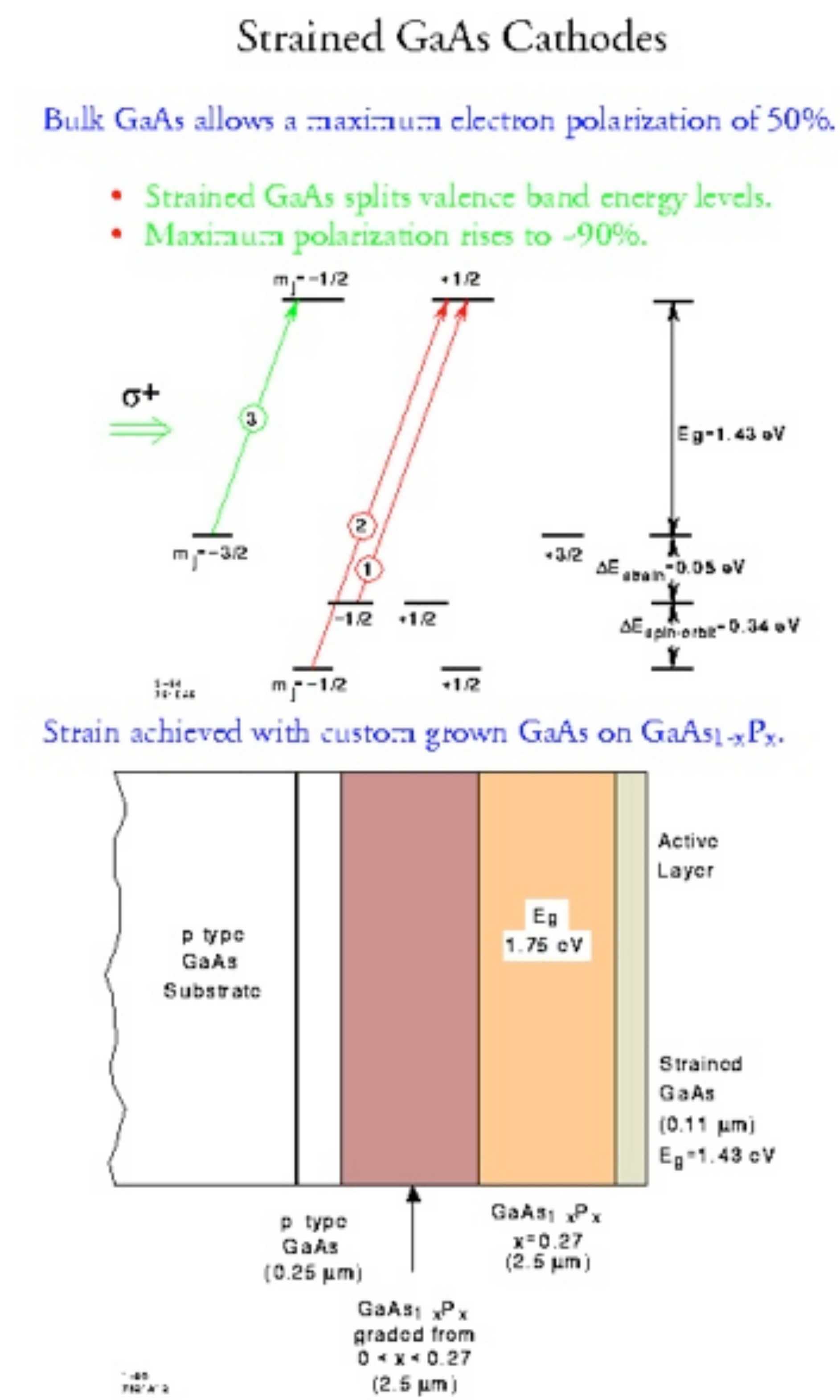

end slides