

# Low energy beam tests, kicker schemes with and without pulse compression, and more

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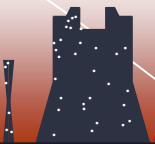
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# Outline

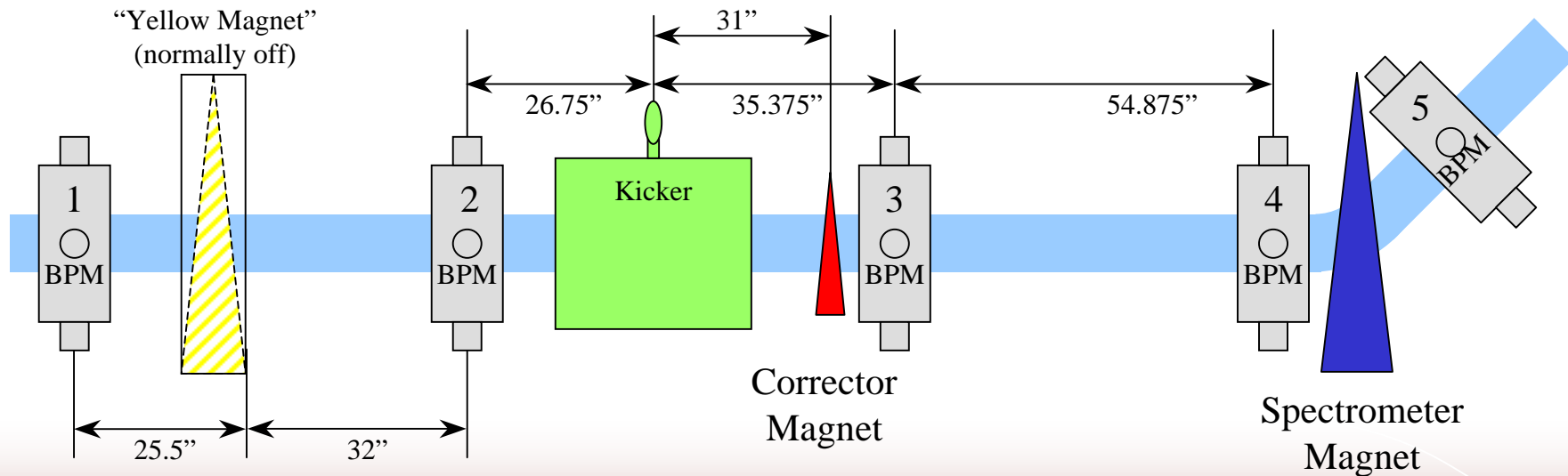
- Low energy beam tests
- Fourier series kicker noise + nonlinearity issues
- Pulse compression using a lossless “all-pass” filter
- A Fourier series kicker without pulse compression
- Hard disk drive write head technology for use in a damping ring extraction kicker?
- Resource issues



# Low energy beam tests

We had used the 16 MeV electron beam at the AØ Photoinjector Lab for kicker tests.

Initial goal was to learn whether or not we could actually do meaningful kicker tests in this beam.

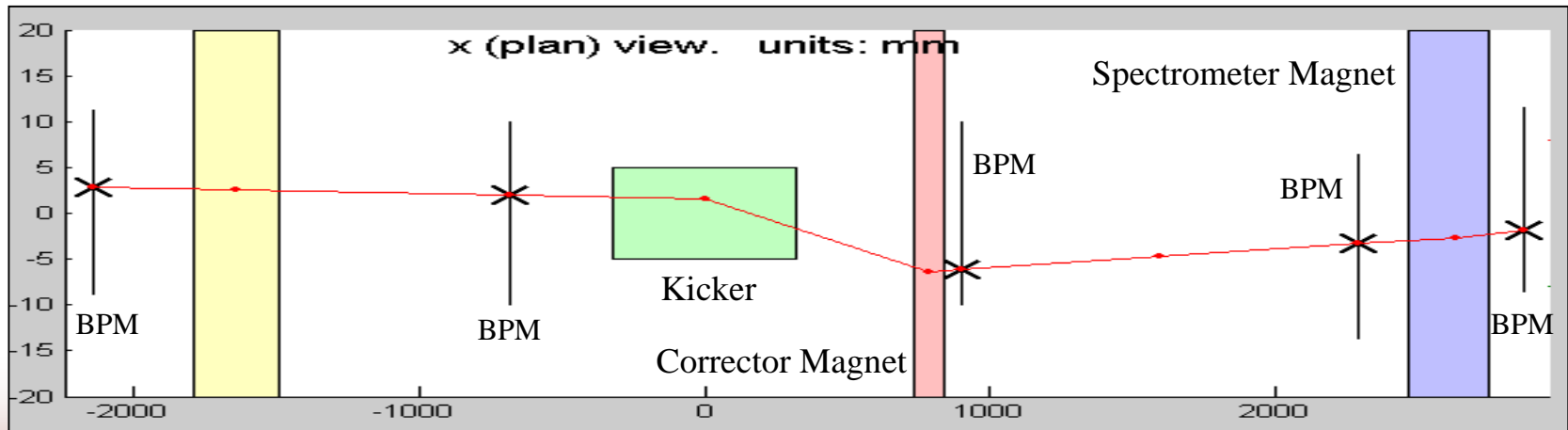


# Low beam energy and lack of redundant measurements...

...made things messy.

Fringe fields from the spectrometer magnet steered the beam in spite of installation of lots of shielding.

Fringe fields from other “normally off” magnets also steered the beam.



# We learned a lot about using $A\emptyset$ this way

BPM resolution was about  $50\ \mu\text{m}$ .

Coupling between  $p$  and  $x, y$  made ballistic alignment complicated.

Trapezoidal-pole spectrometer magnet without an accurate field map limited our ability to momentum-analyze the  $A\emptyset$  beam.

Timing information from phase detector was probably very good, but we'd like a second one to understand that system's precision.

Full Monte Carlo of beam line before installation of components would have helped us avoid a few silly things (goofs in shape of curved pipe through spectrometer, etc.)

# Rough conclusions

Precision momentum and beam trajectory measurements are tricky at this energy with this geometry,

Timing measurements are probably more easily done at  $A\emptyset$  than momentum measurements.

This could be a nice drop-in test facility for various devices, but needs considerably more thought and sophistication in the design next time.

# Fourier series kicker noise + nonlinearity issues

We have been modeling a 1.8 GHz system, with a full bandwidth of  $\pm 180$  MHz.

It would be a high power system, perhaps 60 kW or more.

Our kicker simulations indicated that the most significant issue to be addressed would be a third-order nonlinear effect.

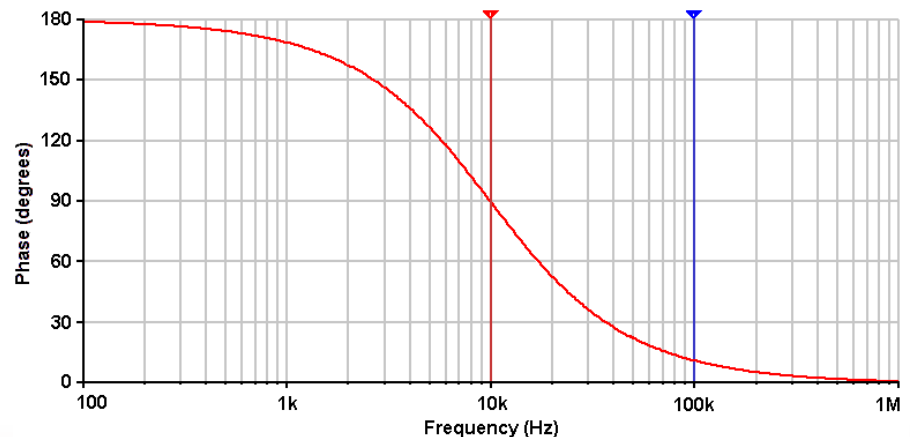
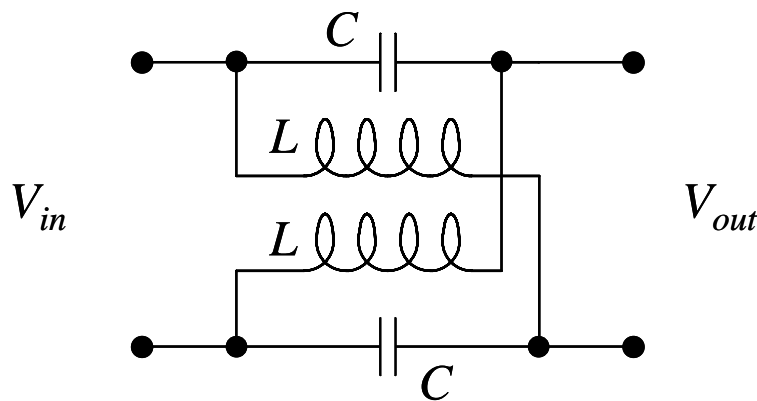
- second-order terms at approximately twice the signal frequency (caused by harmonic distortion and intermodulation distortion) could mix with amplifier noise to produce an in-band contribution that cannot be eliminated.
- It is difficult to evaluate the ultimate impact of this effect without building a prototype device.

# Pulse compression using a lossless “all-pass” filter

Impressive RF filters can be built using PC board technology.

Could we make a pulse compression system using the phase shifts effected by a series of “all pass filters?”

Low frequency:  $V_{out} = -V_{in}$ . High frequency:  $V_{out} = +V_{in}$ .



A very large number of stages would be required

Phase shift for a single stage is approximately  $33^\circ$  per octave at its steepest point.

A Fourier series kicker running with a center frequency of 1.8 GHz needs a phase shift of  $\sim 300^\circ$  between adjacent Fourier components. (Components are separated by  $\sim 3$  MHz.)

It would take a  $\sim 4000$  stage filter to do this!

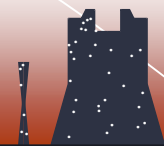
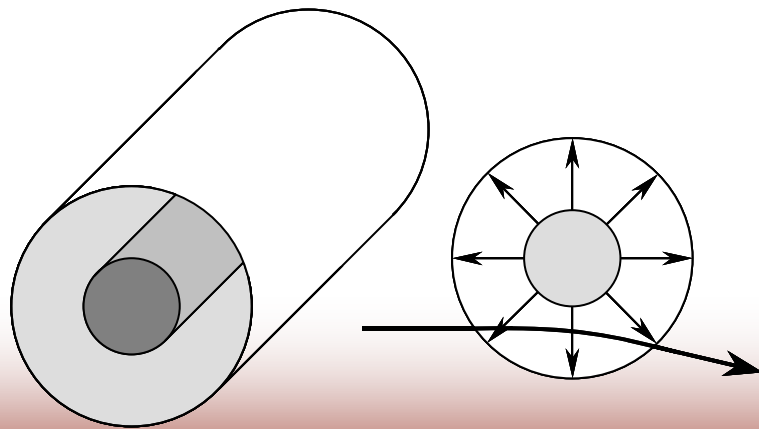
Ouch.

# A Fourier series kicker without pulse compression

Could we build a kicker from a small number of structures, each of which is loaded with several modes?

It's not possible with rectangular structures: the  $x$ ,  $y$ ,  $z$  boundary conditions force the frequency spectrum to have the wrong inter-mode spacing.

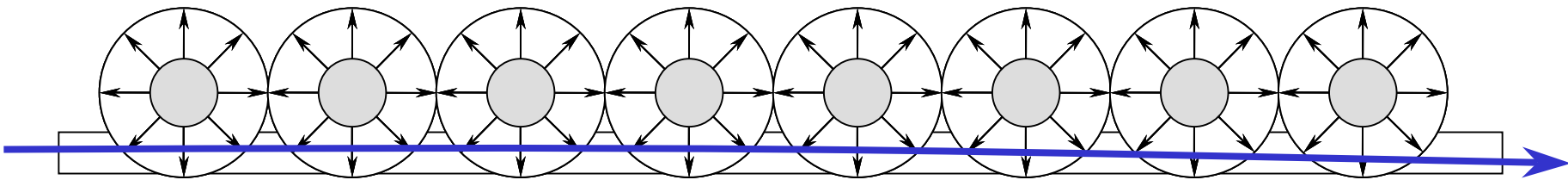
We found that (long) structures using a concentric cylindrical geometry would have the right mode structure:



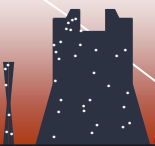
# “Pan pipe” kicker

The longest structure would have a 3 MHz fundamental. Eight structures of varying lengths would be required.

We haven't modeled the effects of beam entry/exit ports.



There are some advantages (and disadvantages) to this: lower power, etc. etc.



# Hard disk drive write head technology for use in a damping ring extraction kicker?

We always think about spatially fixed devices and moveable beams.

BUT could one build an extraction kicker that was a sort of hard disk write head on steroids?

Hard disk write head (from discussions with Hitachi):

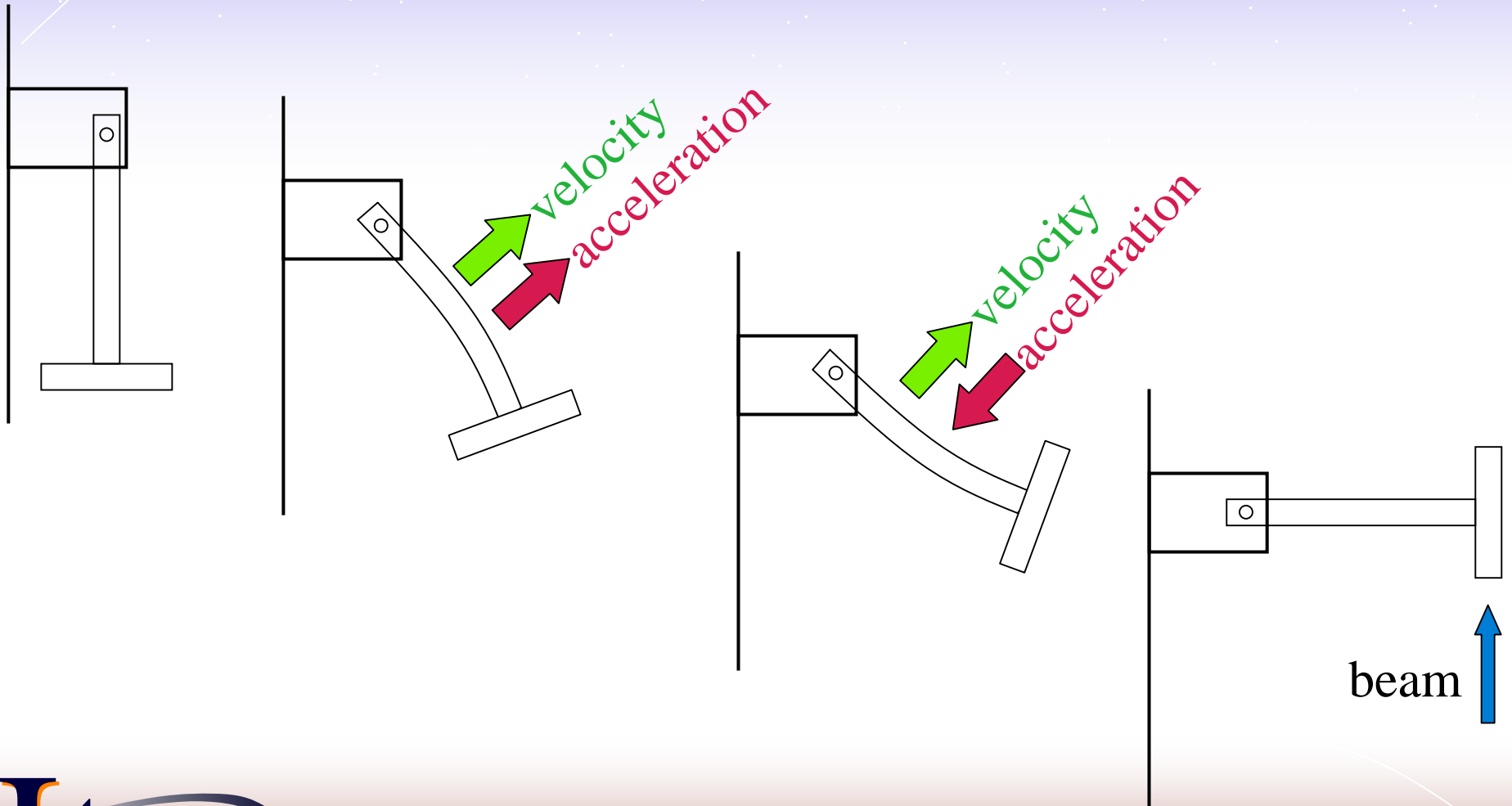
- 1 T field strength
- field direction can be changed at 1 GHz (soon 2 GHz)
- field volume is small,  $\sim 120 \mu\text{m}^3$  including flux return
- head positioning is accurate to a few nm

Extraction kicker needs 1 T·cm field integral. Can HDD head be scaled up?



# Head movement

Program acceleration/deceleration to minimize vibrations:



# Field volume

Damping ring beam at extraction:

$\pm 3 \sigma_x$  and  $\pm 3 \sigma_y$  requires  $1200\mu\text{m} \times 60 \mu\text{m}$  aperture

Kicking field: 1 T inside  $1 \text{ cm} \times 1200\mu\text{m} \times 60 \mu\text{m}$  aperture gap.

Field volume is  $\sim 10^7$  times greater than disk write head, not including kicker magnet flux return.

Uh oh. Disk head magnet current drivers use  $\sim 50 \text{ mA}$  per head, need a few volts drive voltage.

Too much peak power. Rats.

# Resource issues

Comments from the speaker: working on accelerator R&D at a university.

- people, time, facilities
- partnering with national laboratories
- doing things differently

