Picosecond X-ray Detector for Synchrotrons

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Outline

- Explain Project
- Explain Design/Production Process
- What I've Done
- Summer Goals, an Overview

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Ultrafast Physics

- Time Domain: $\leq 10^{-12}$ seconds (ps)
- Generally lasers/optical detectors

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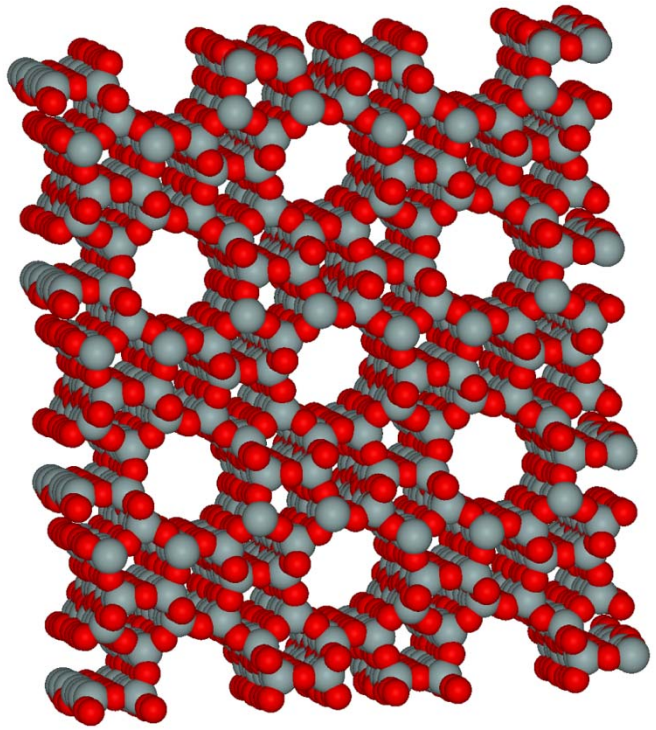
Uses

- X-ray wavelength corresponds to distance between atoms
- Look at changes in atomic structure as they occur



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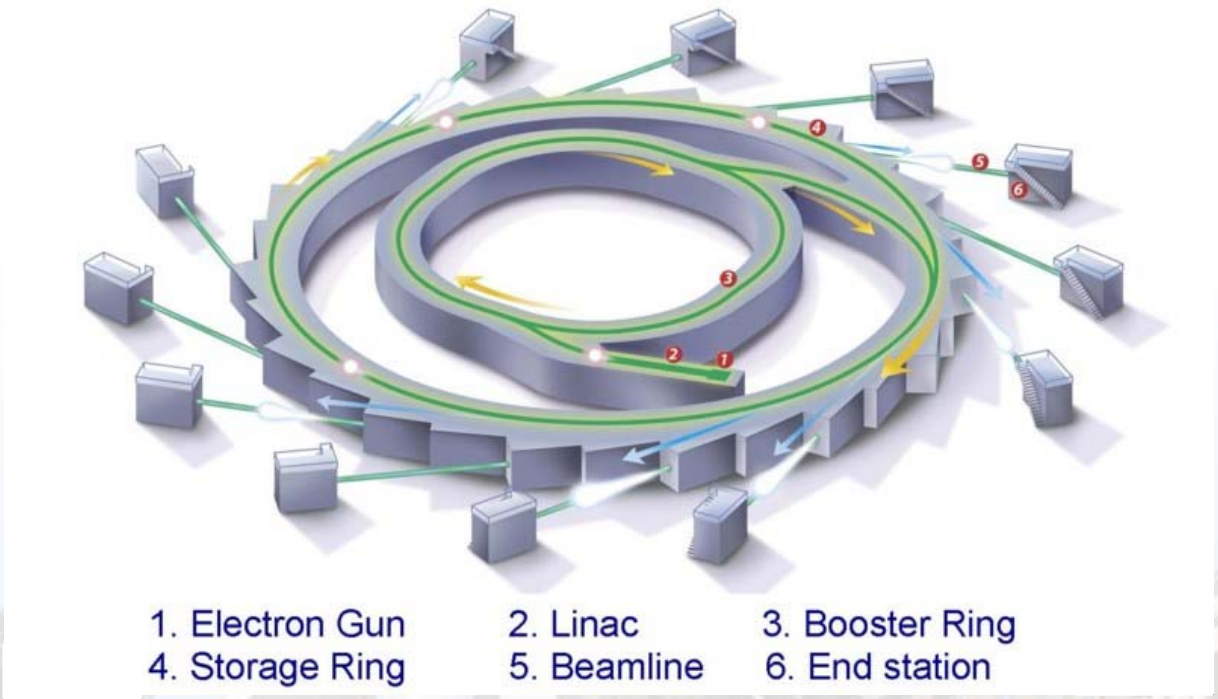
Synchrotrons

- Circular particle accelerator



- X-ray radiation, ~100 ps pulse
- Faster detectors needed

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Project Overview

- Starting Point:
  - Previous work
  - Recreate results, then modify
- Fattinger and Grischkowsky
- Transmission lines
- Terahertz radiation

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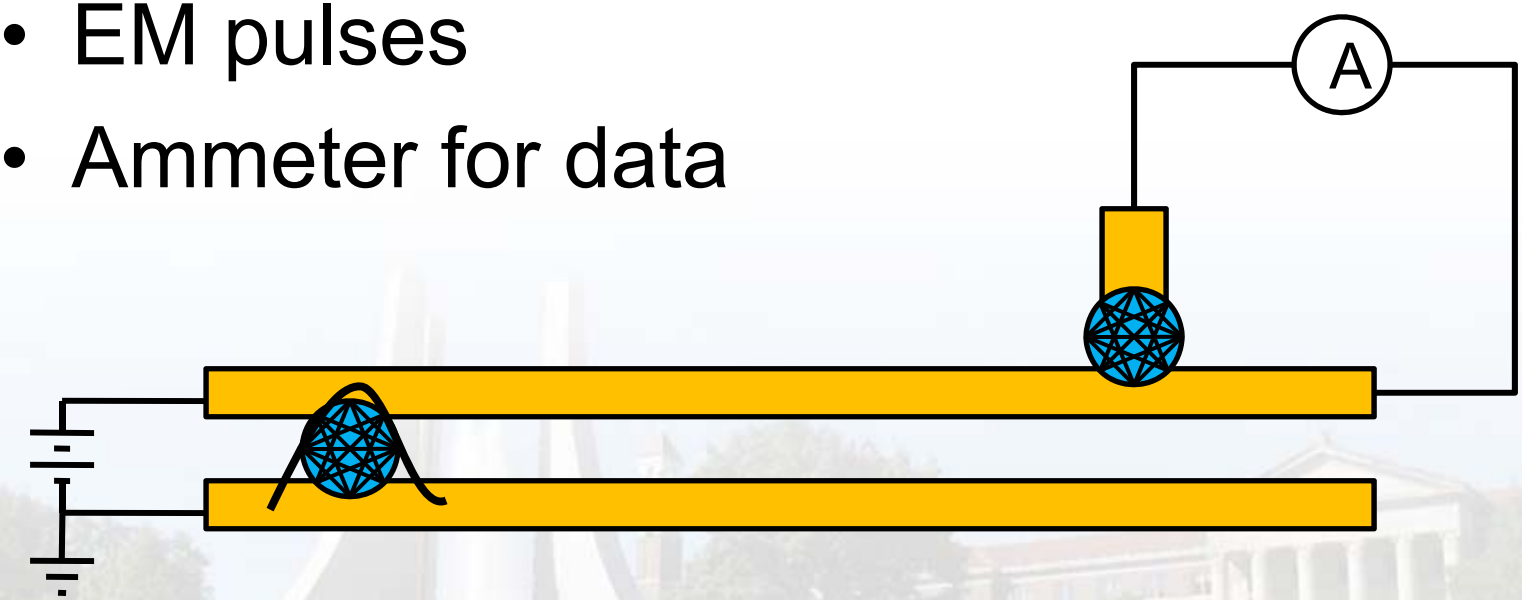
The Detector (Design)

- Gold on semiconductor with defects
- Coplanar transmission lines
- EM pulses
- Ammeter for data



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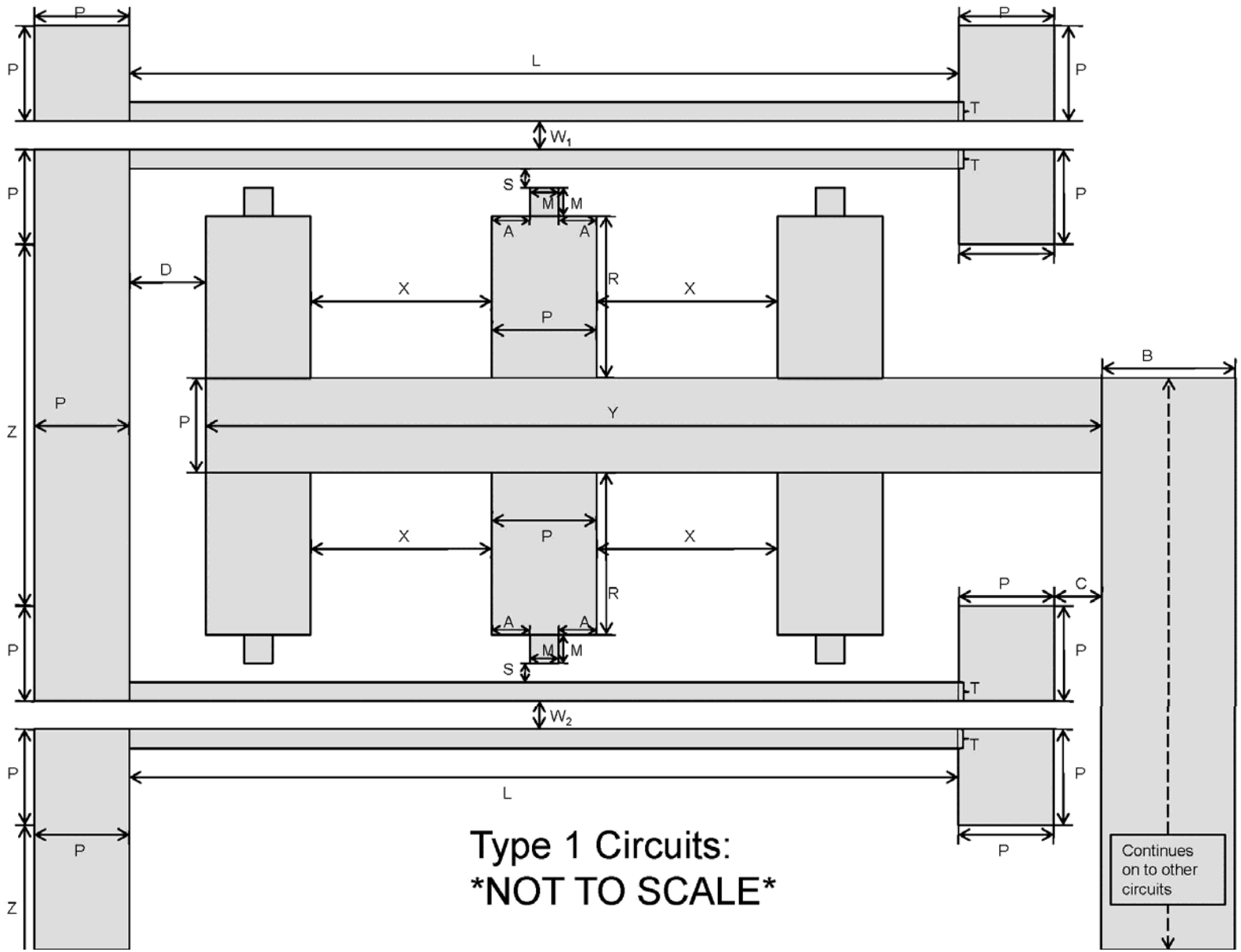
The Detector (Design)



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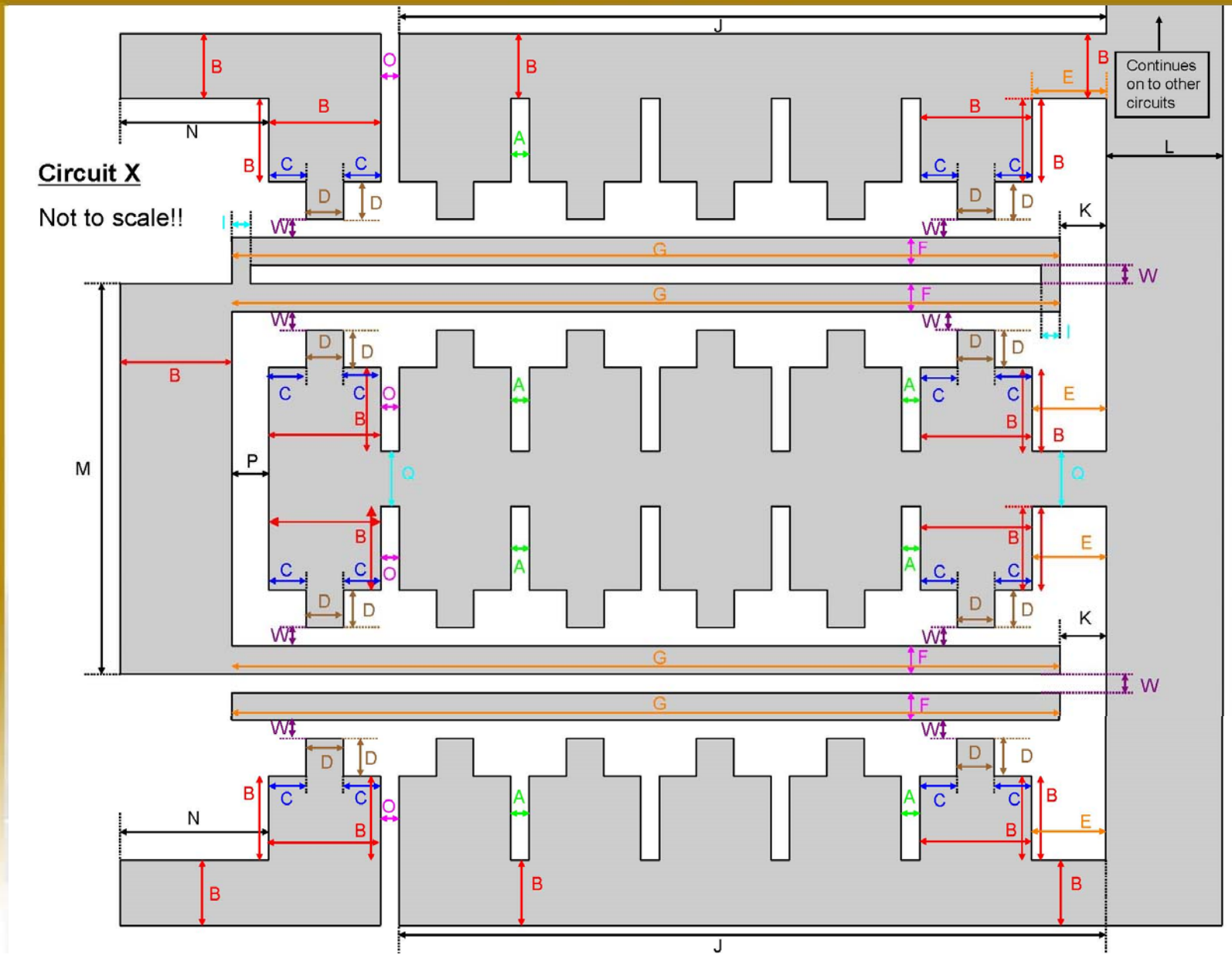
The Detector (Design)



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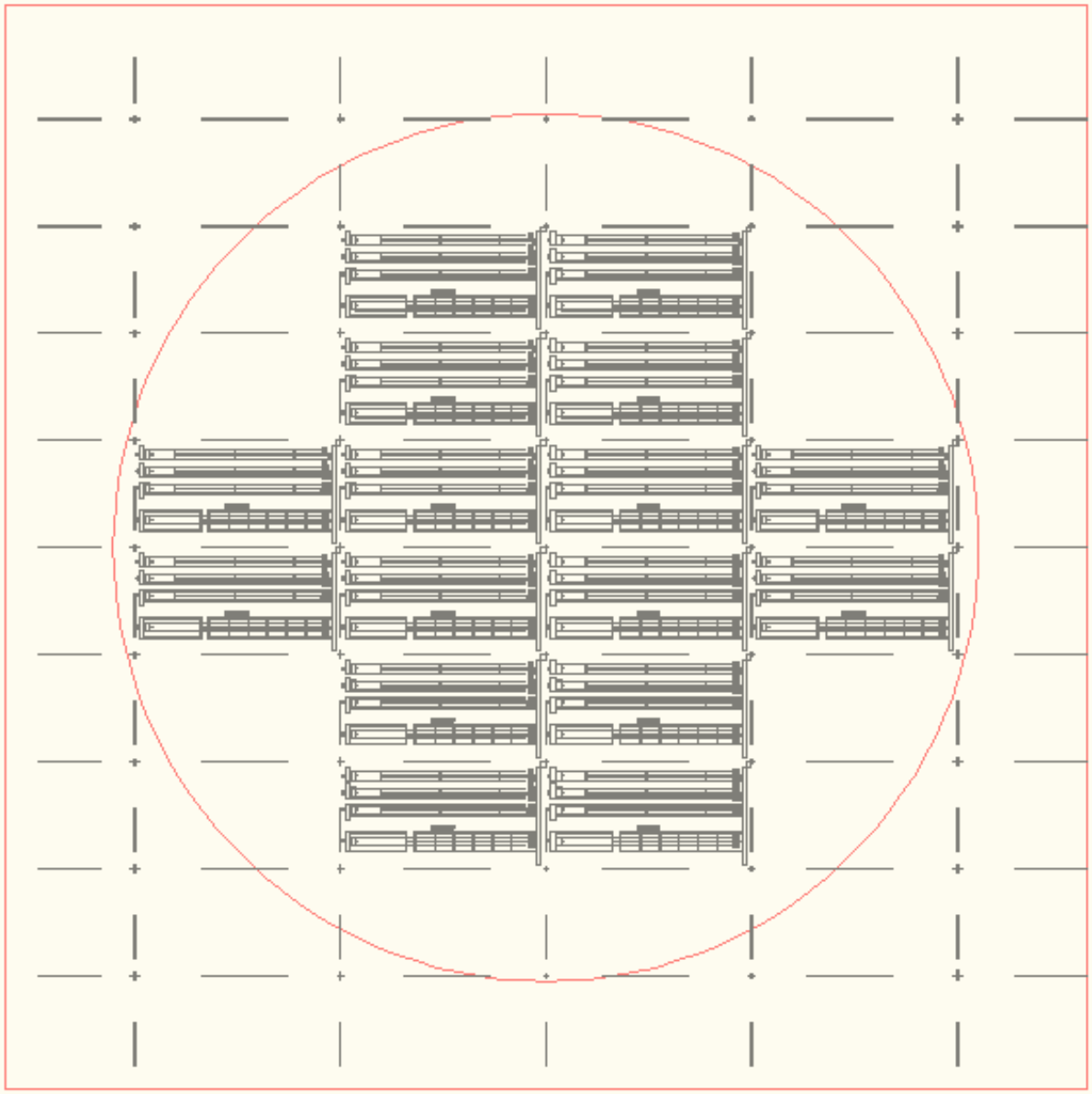
The Detector (Design)

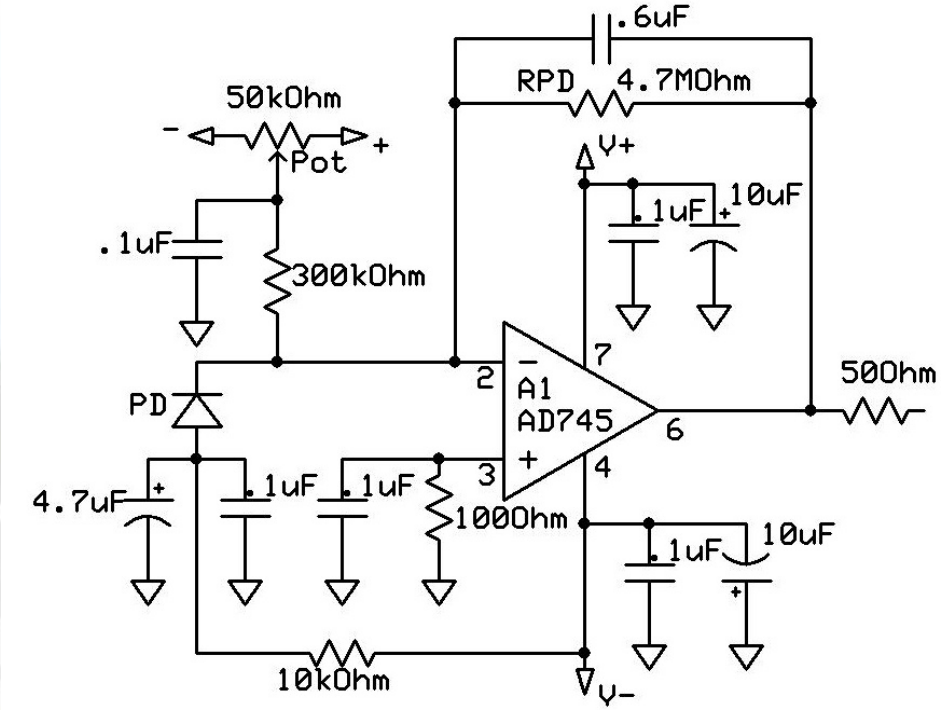


The Detector (Design)

- Aamer Mahmood, Birck Nanotechnology Laboratory
- Designs and packaging
- Gold on Si

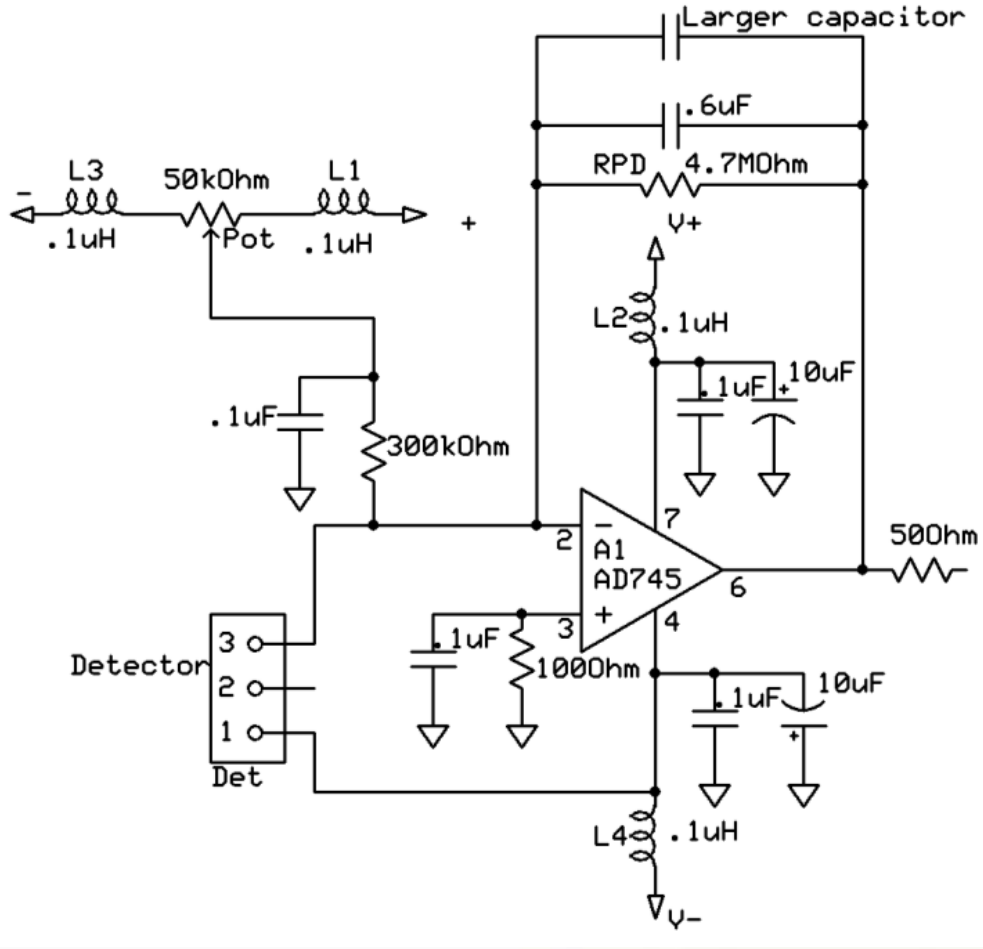
The Amplifier

- Custom amplifier, ultralow noise
- Starting Point:
  - Sergei Savikhin's design
  - OP Amp AD745



The Amplifier

- Met with Sergei Savikhin
- Tailored design to fit our needs



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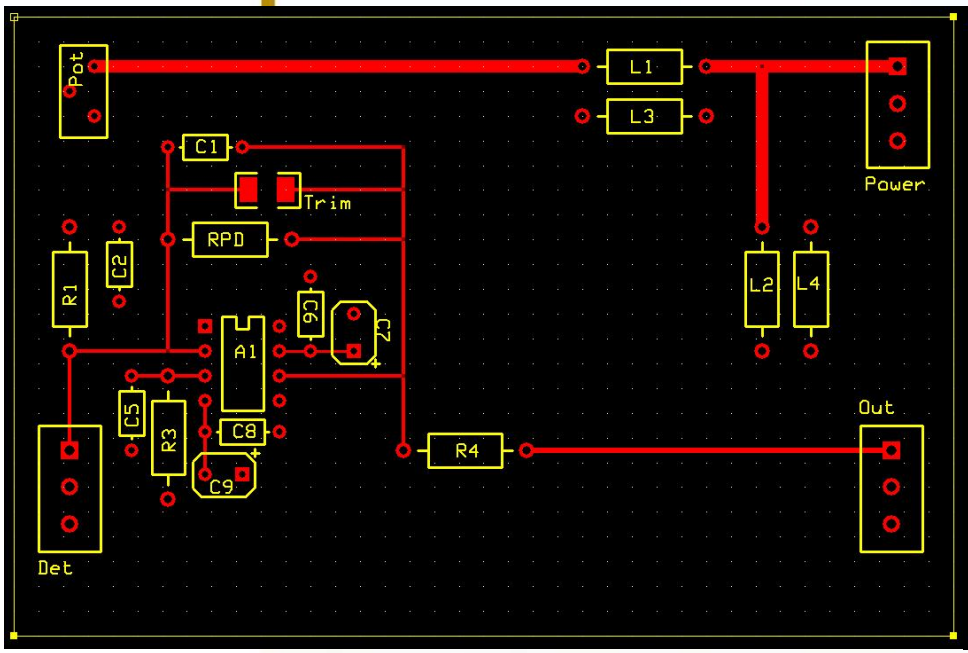
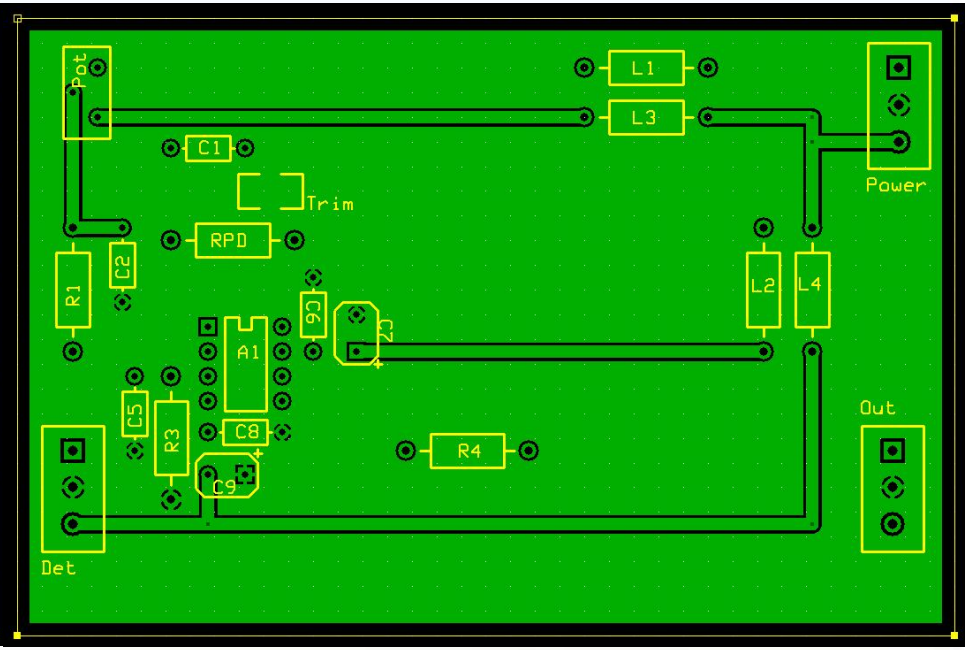
The Amplifier

- Met with Mark Smith
- Designed, ordered, and built PCB
- Tested amplifier with photodiode

Top Side



Bottom Side



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Savikhin's Lab

- Goals:
  - Practice working with laser
  - Create setup for later use
- Test piece:
  - Similar design on GaAs
  - Larger gap sizes, shorter line lengths

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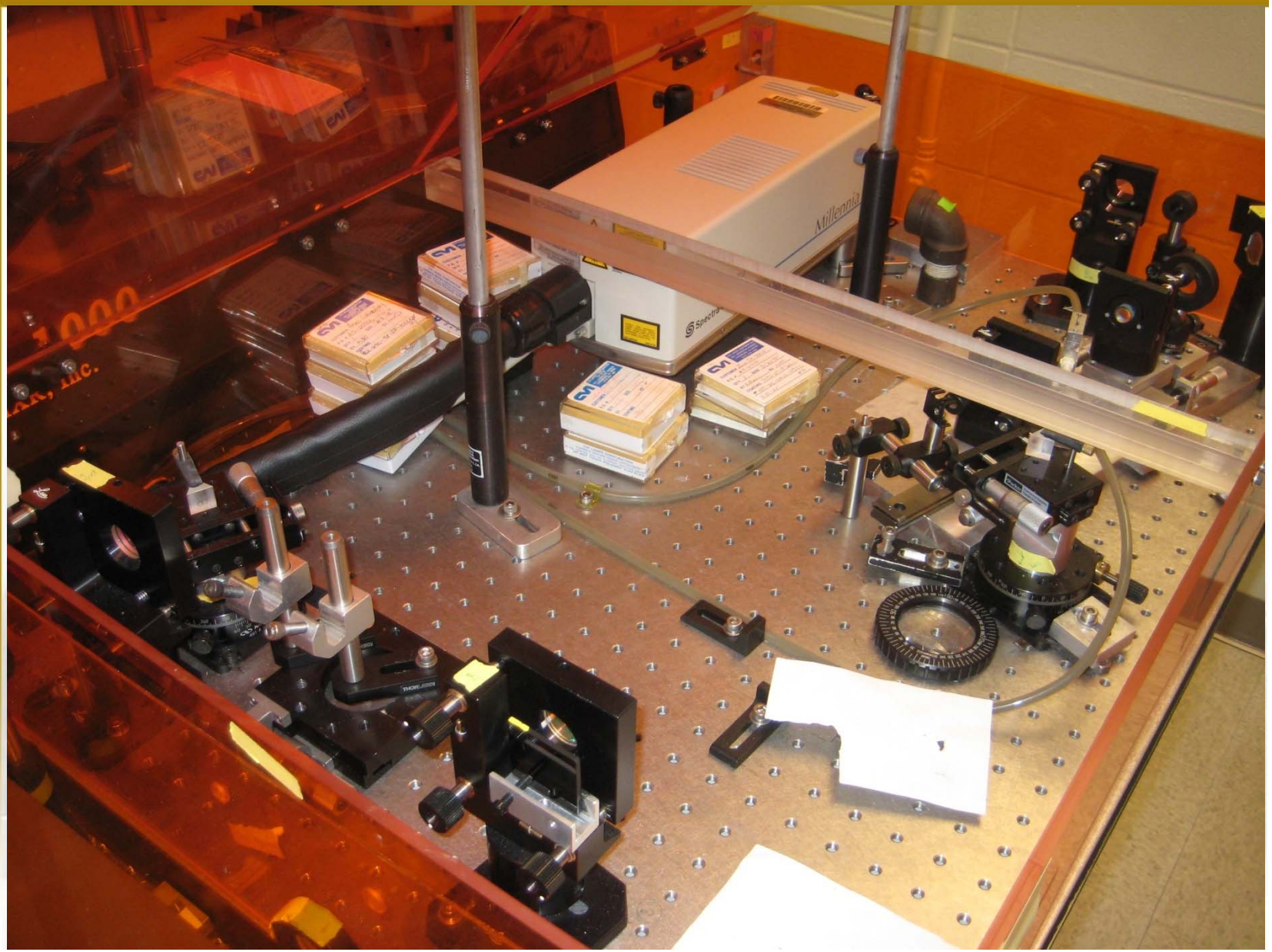
Savikhin's Lab



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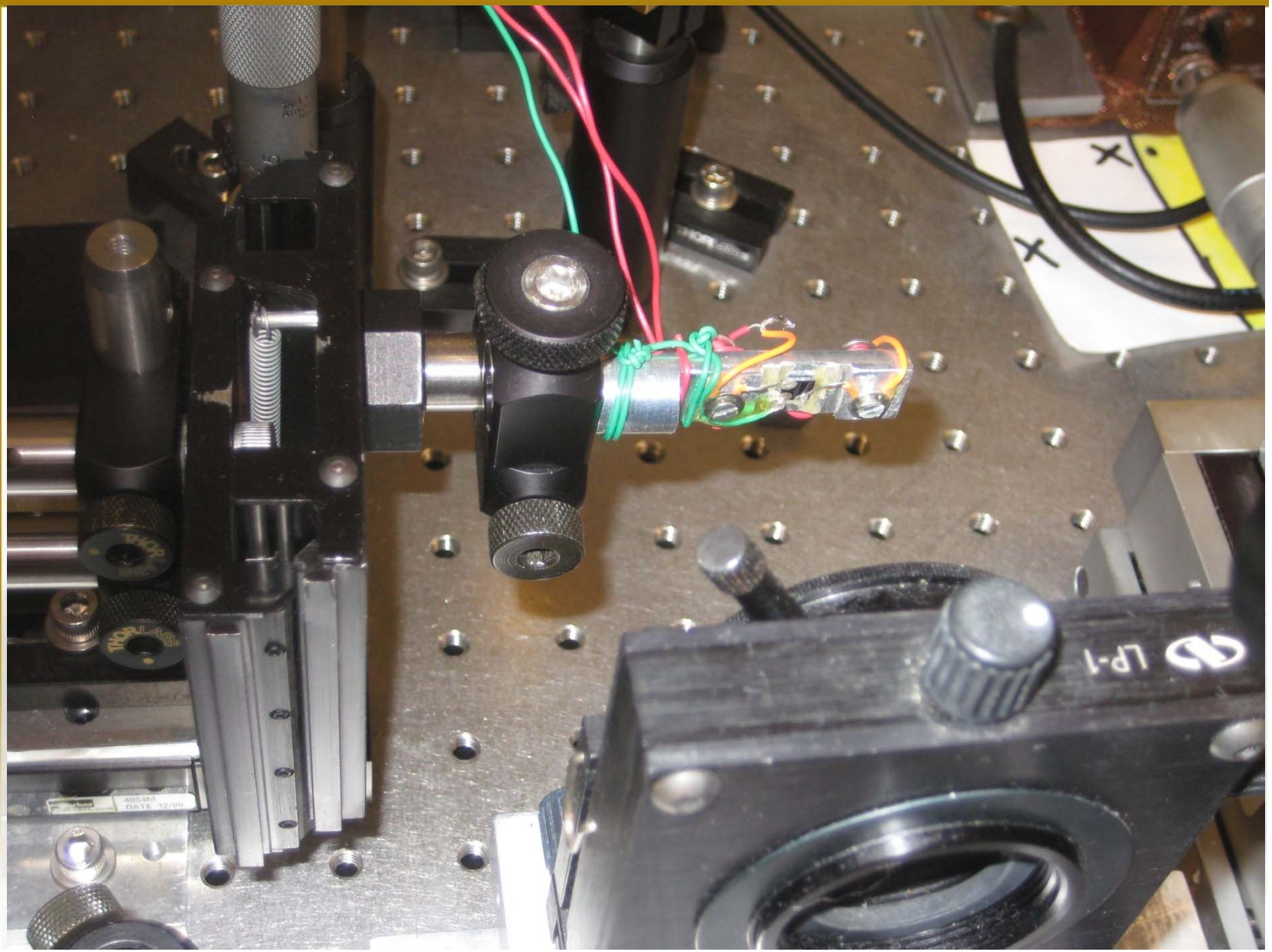
Savikhin's Lab



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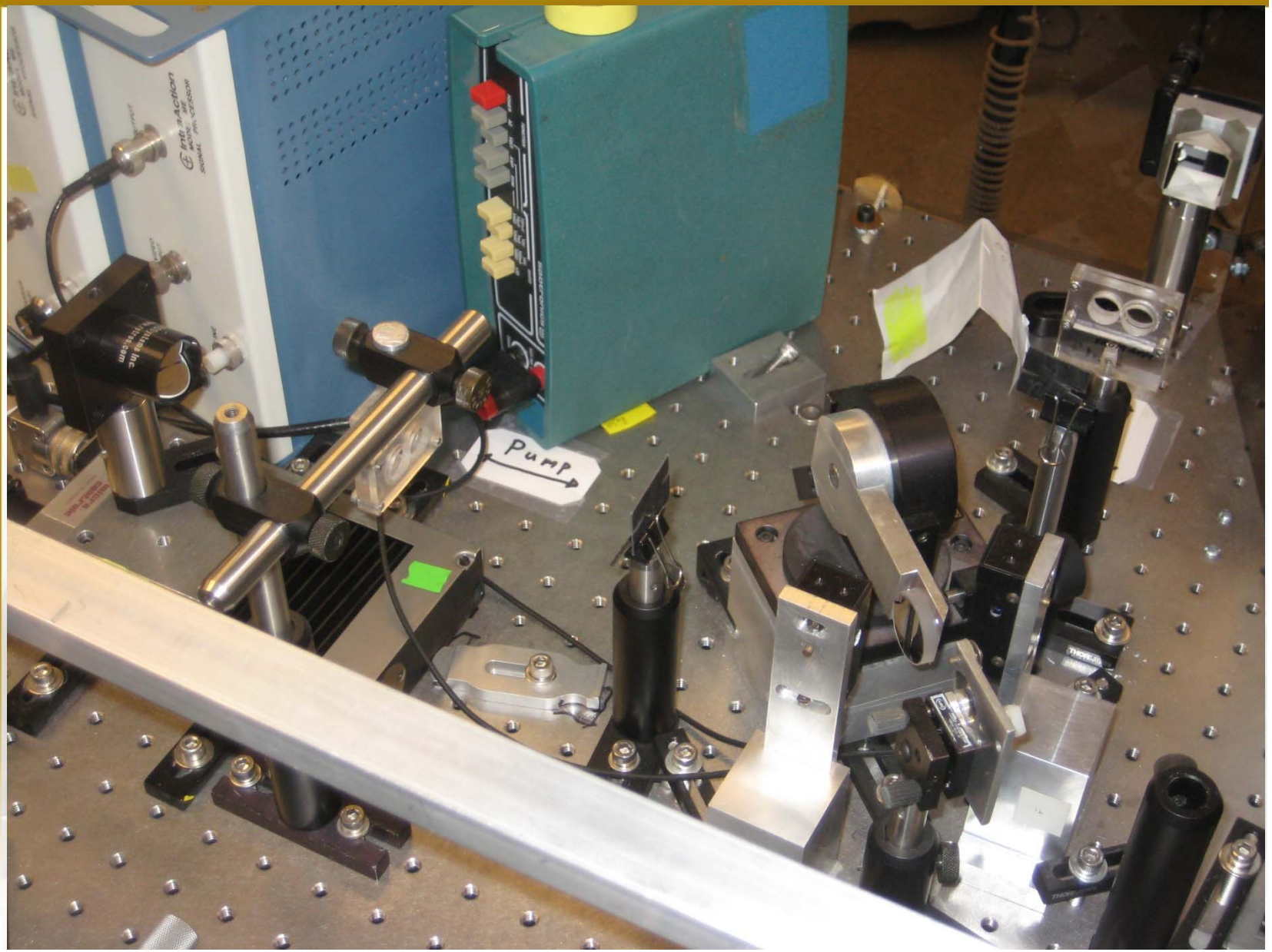

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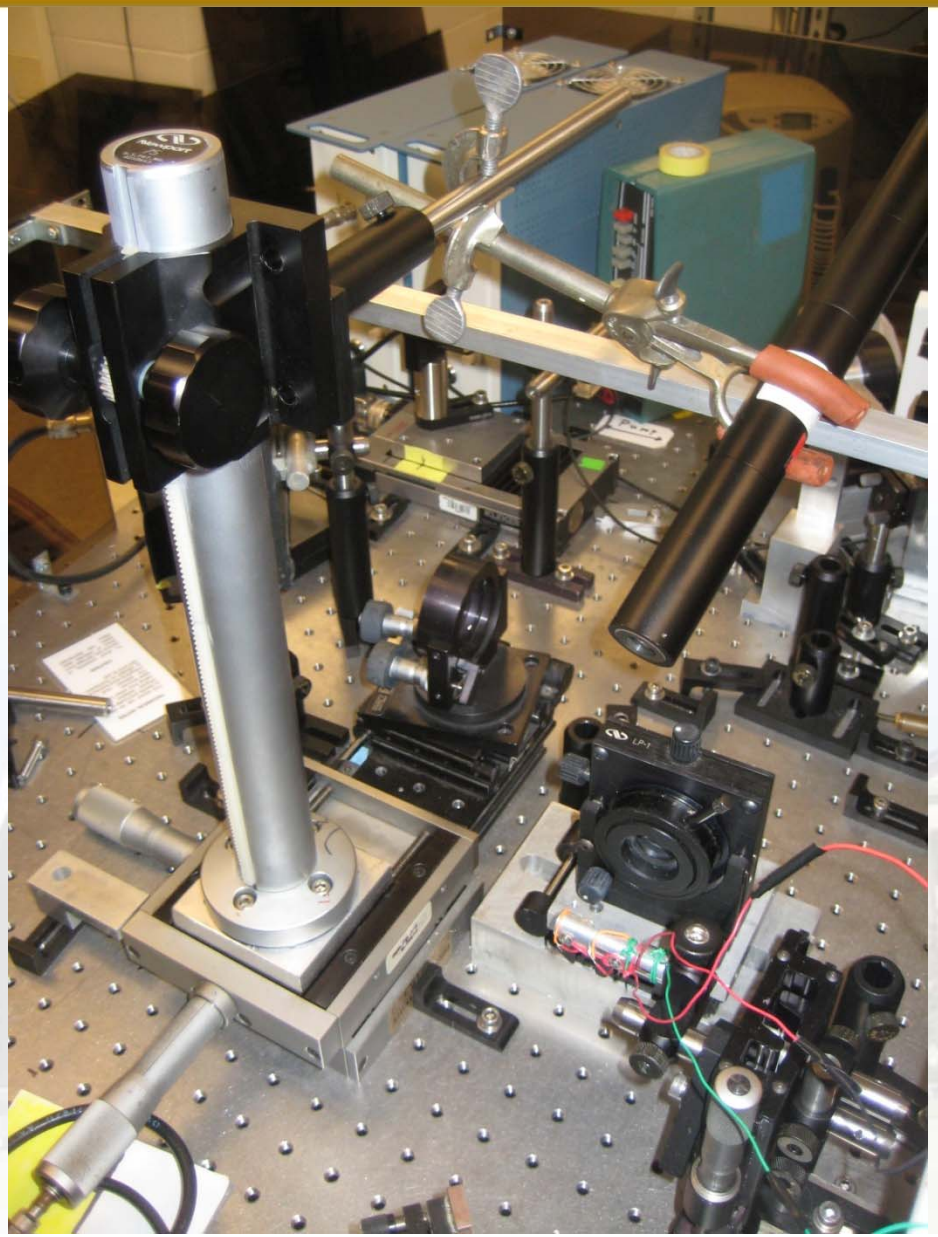
Savikhin's Lab



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Savikhin's Lab

- Procedure 1: Make it work
  - Hook up the detector correctly
  - Point the beams at the sample
  - Collect data using long time delay
- Procedure 2: Make it work *well*
  - Optimize beam locations
  - Search for peaks
  - Investigate times of interest

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Savikhin's Lab

- Issues
  - Very noisy data
  - Didn't find expected peak
  - Found an unexpected peak
  - It broke

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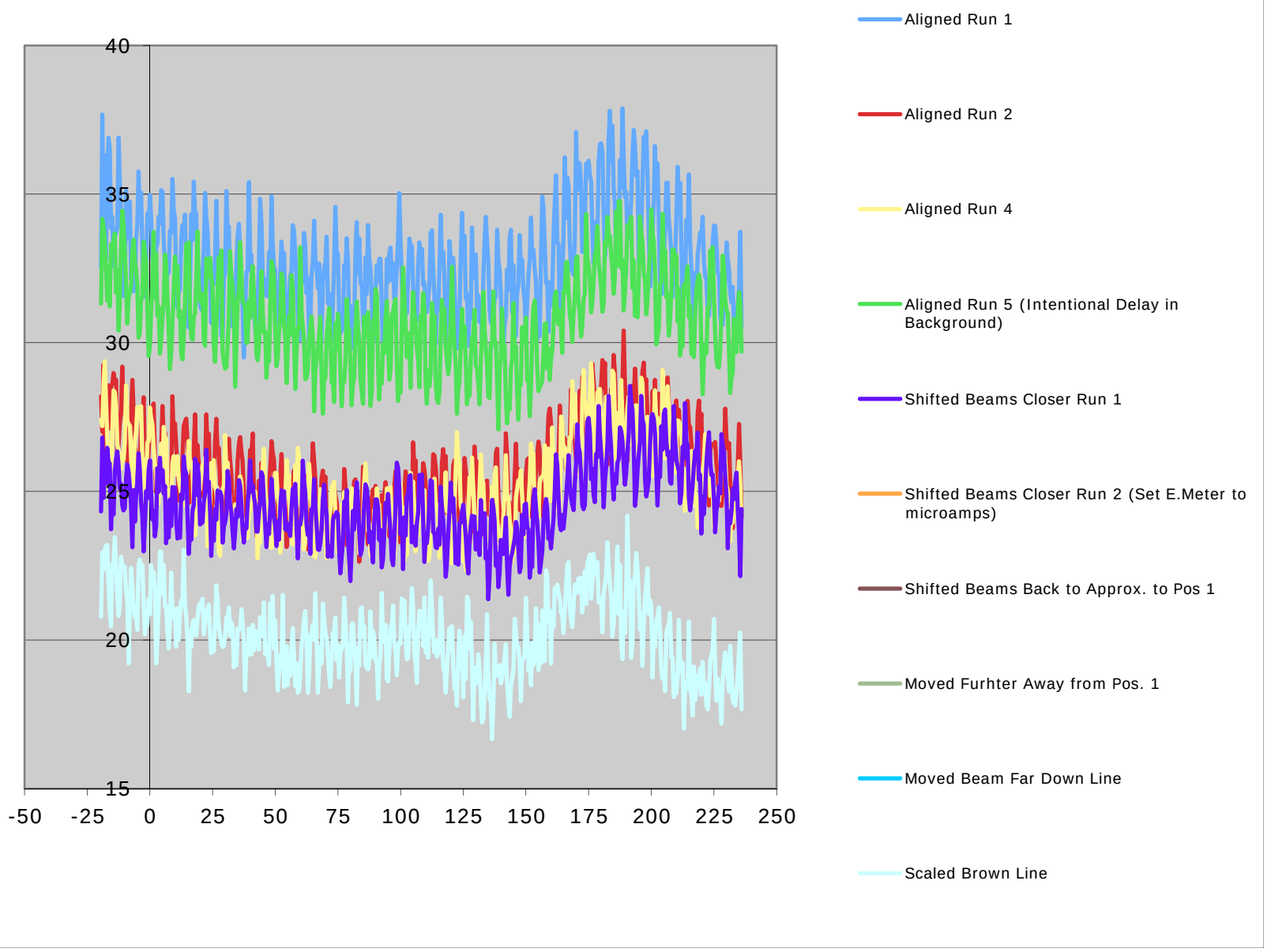
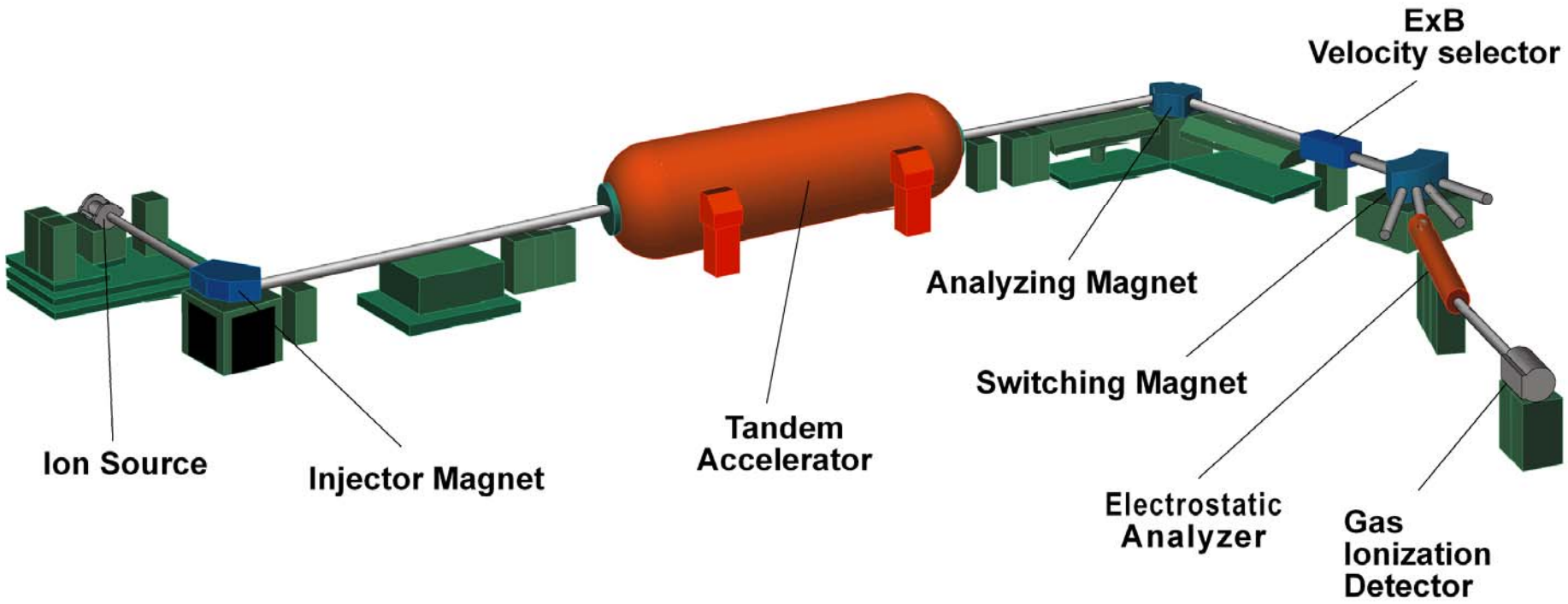
Savikhin's Lab



The Detector (Production)

- Birck completed samples
- Marc Caffee, PRIME Laboratory
- Deep ion implantation
- Reduced carrier lifetime



The Detector (Production)

- PRIME Lab Setup:

PURDUE UNIVERSITY The Detector (Production)

← 15 hours in here

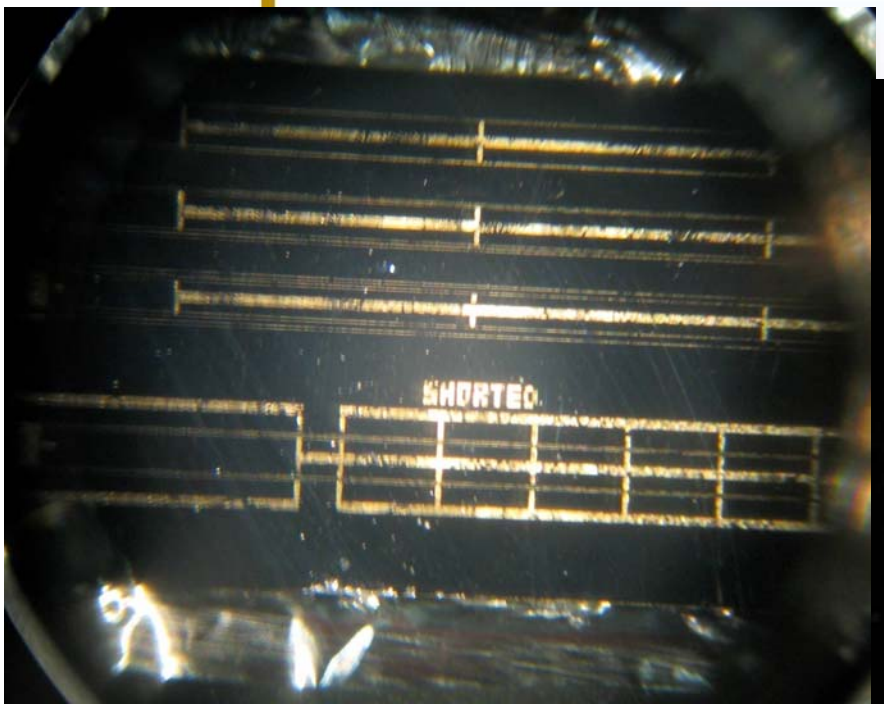
Controlling this →

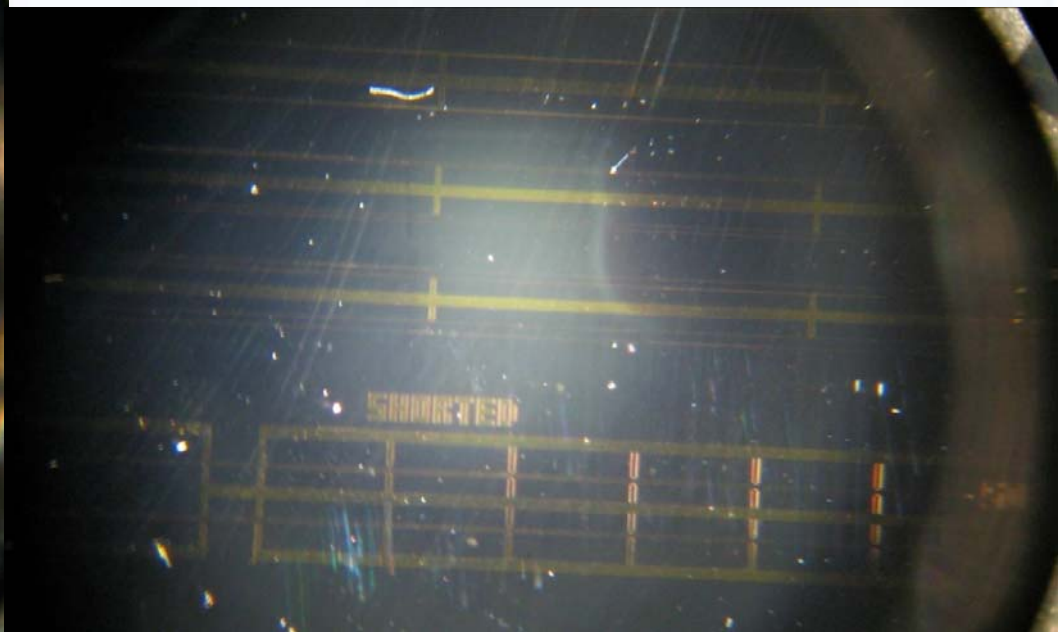
The Detector (Production)

- Implantation:
  - How many protons?
- Radiation issues
  - Pulled samples out, very radioactive
  - Stainless steel mount was the cause

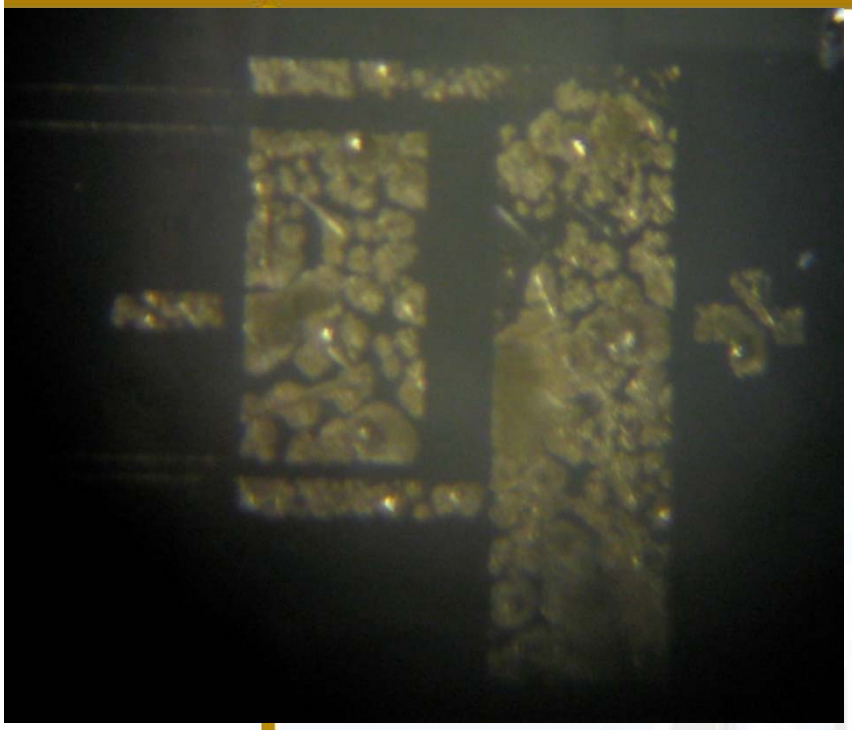
The Detector (Production)

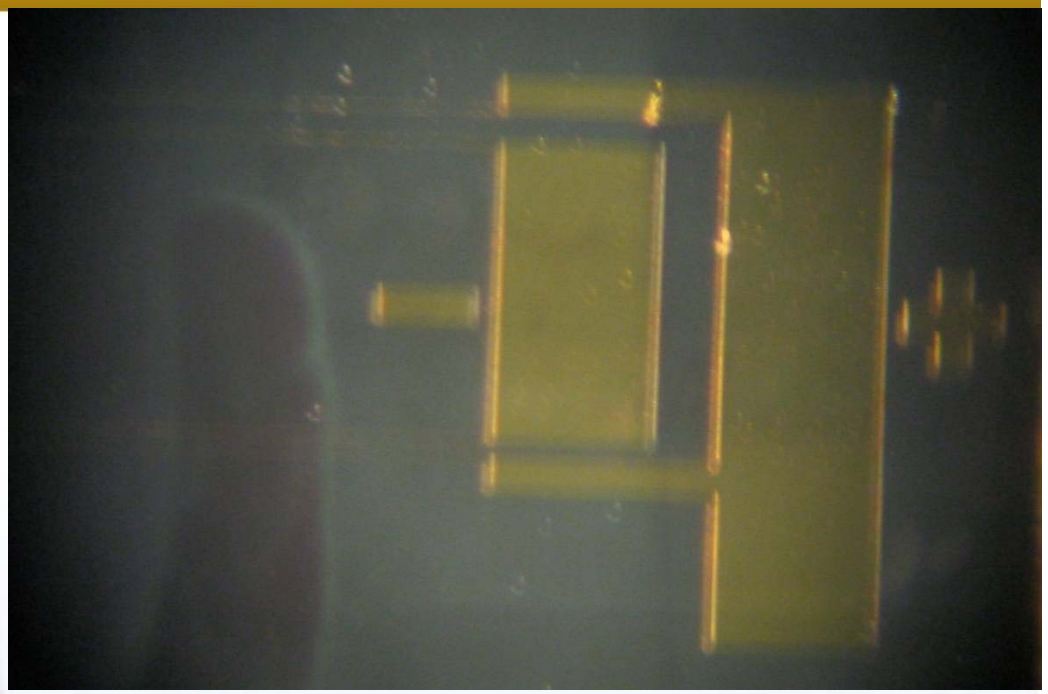
- Samples melted with high current (1 μA)
- Decreased current to solve (100 nA)

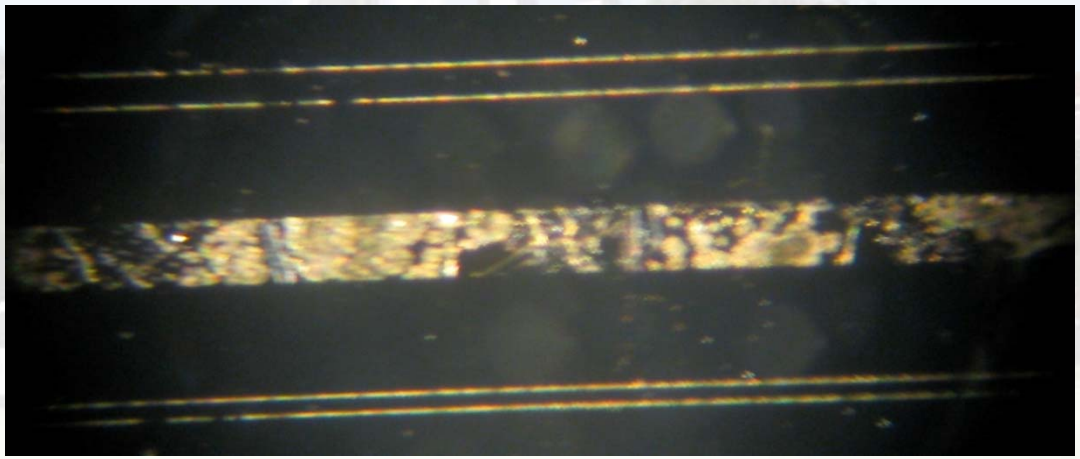




The Detector (Production)

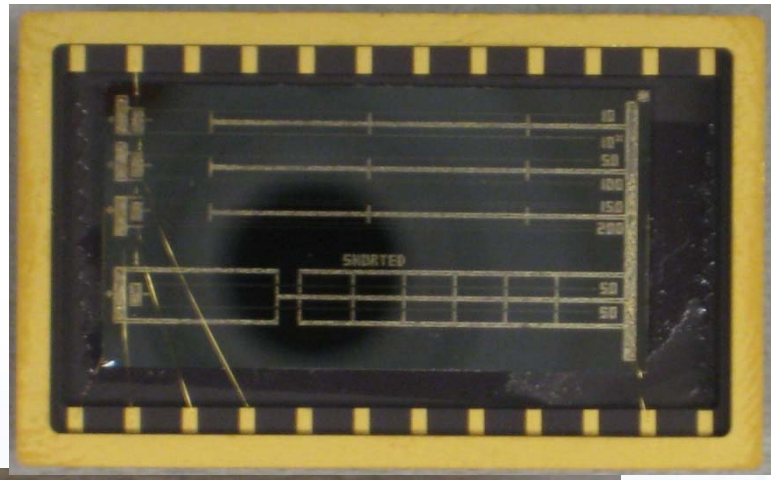


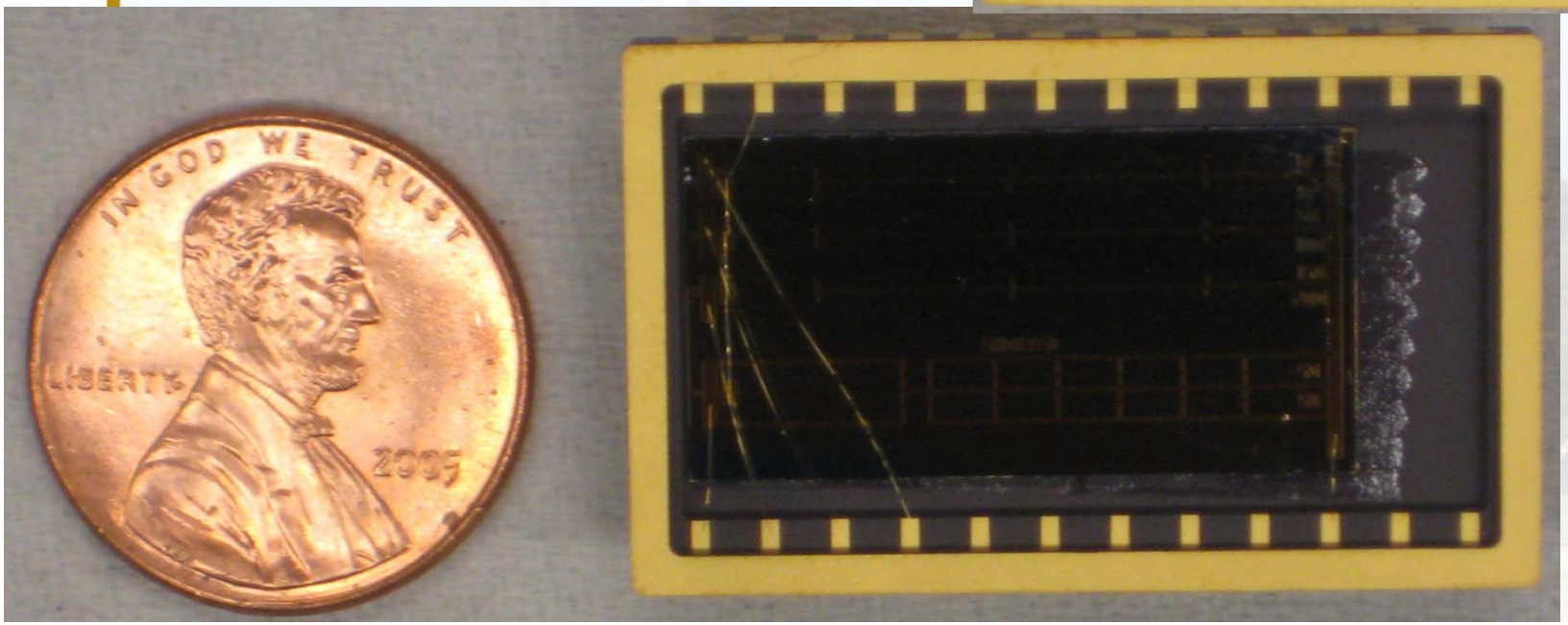




The Detector (Production)

- Back to Birck: Wire bonding
  - 25 μm wires
  - 24 pin DIP package
- Circuit board needed for sample





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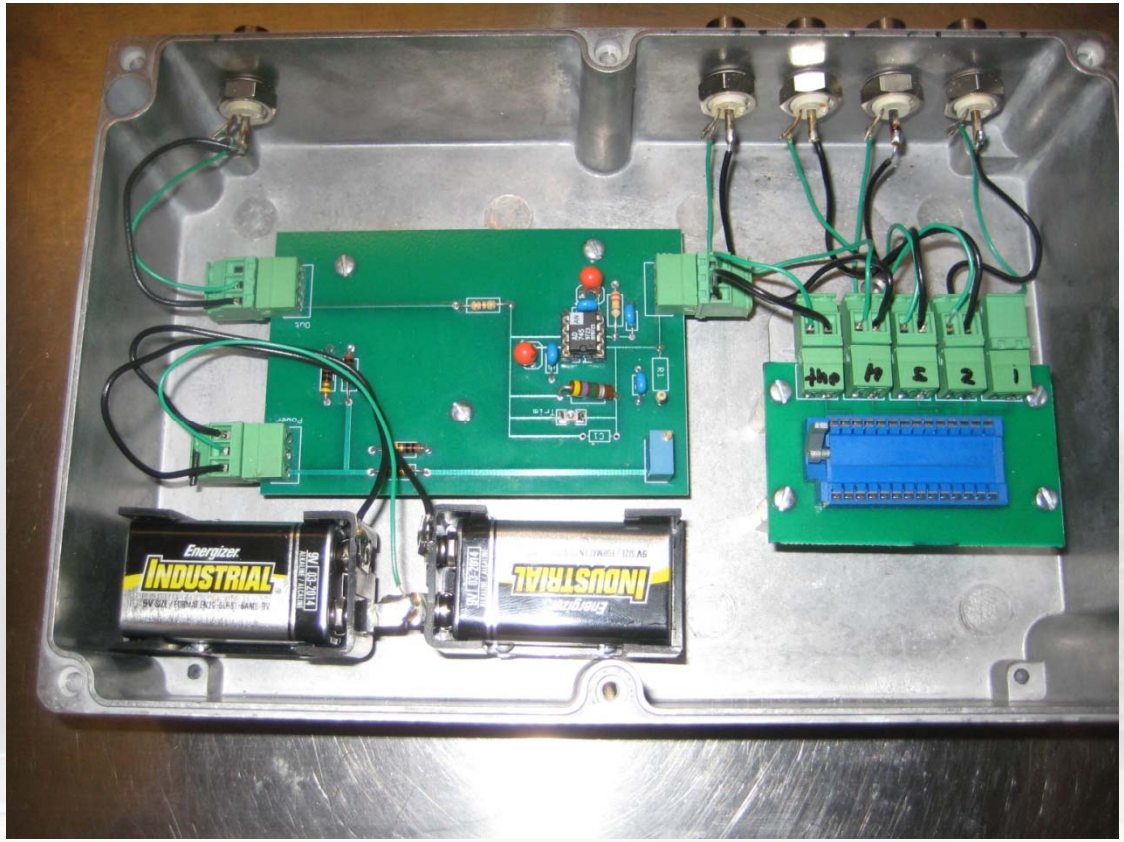
Detector Case

- Requirements:
  - Holds power, amplifier, and detector
  - Input and output jacks
  - Sturdy



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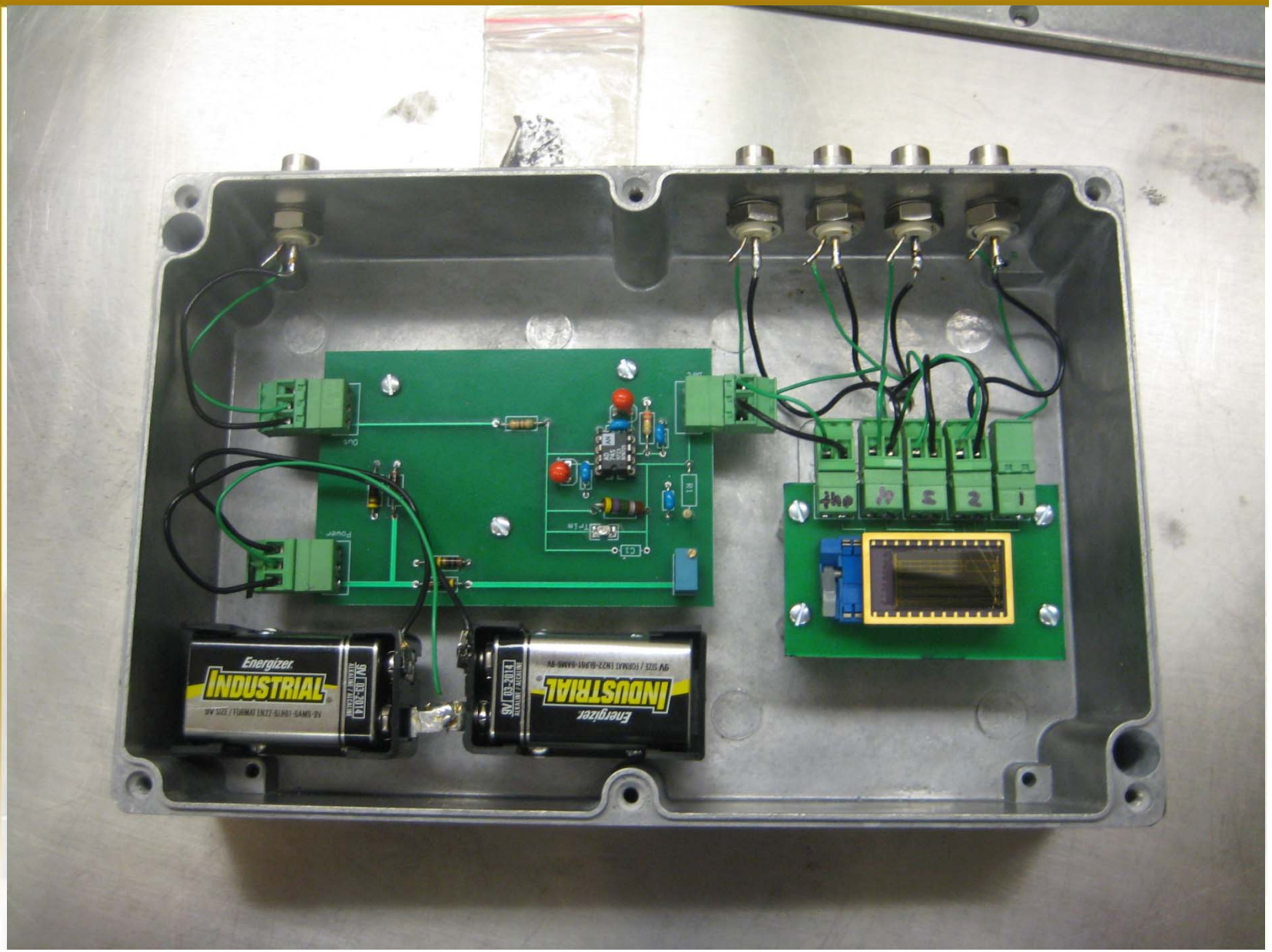
Detector Case



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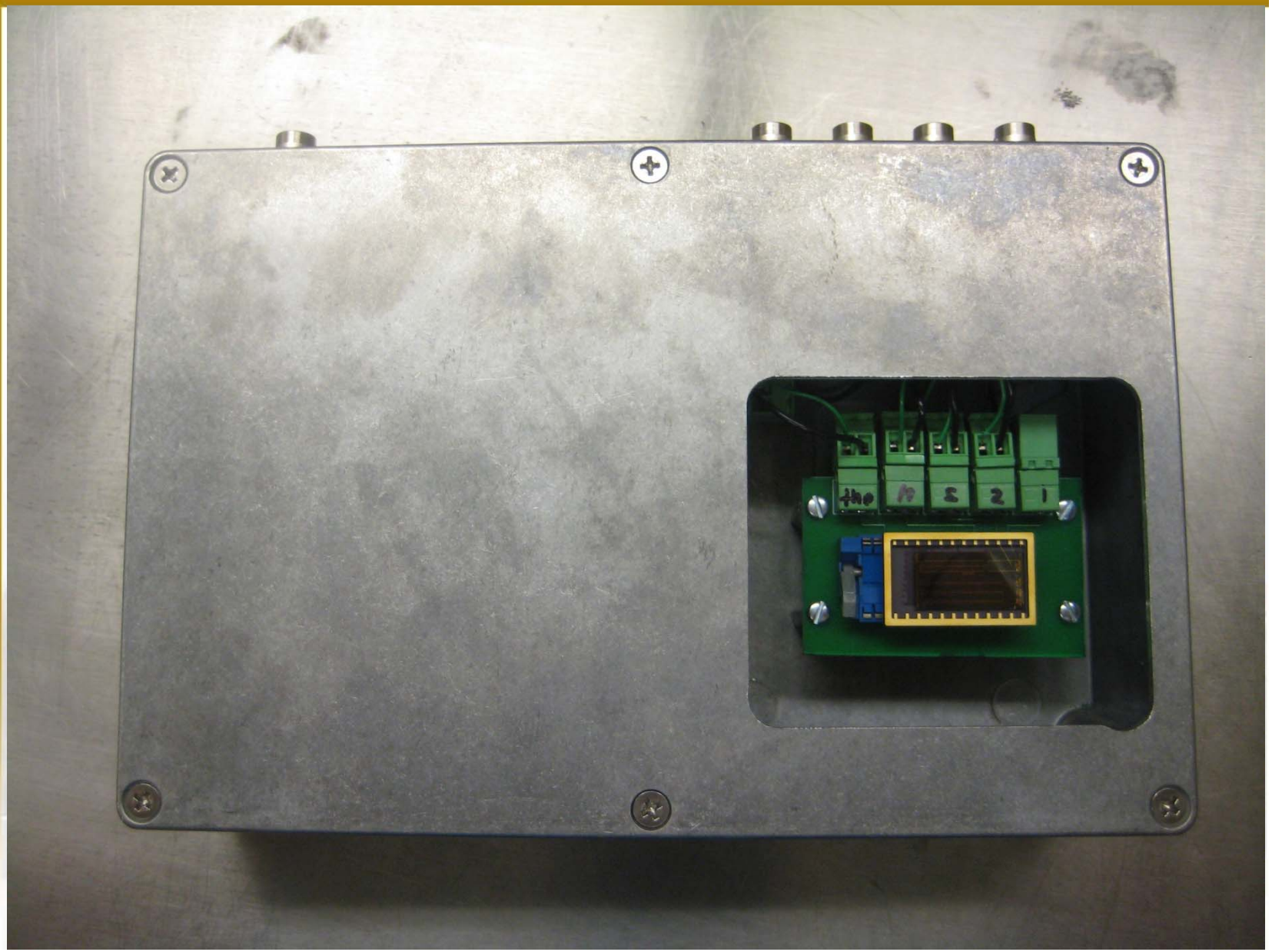
Detector Case



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Detector Case

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Summer Goals

- Get the detector built: Check
- Get the detector implanted: Check
- Test the detector: Savikhin's lab
  - Equipment training: Check
  - Tests…In process
- Test the detector at APS: Next Week

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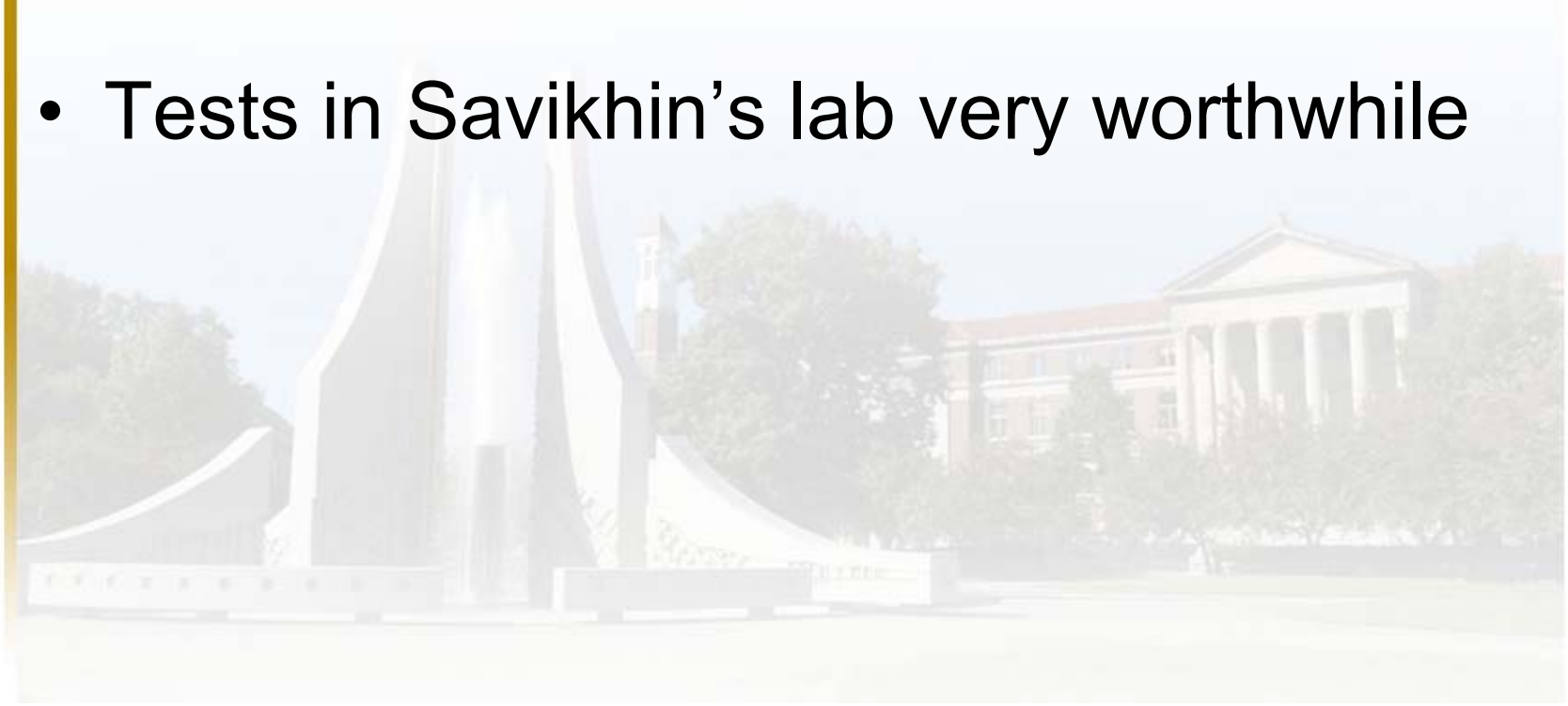
Closing Thoughts

- Design/Production went fairly smoothly
- Fast production schedule was a good experience
- Tests in Savikhin's lab very worthwhile