Joint Development of SiGHT

a low background Silicon Geiger Hybrid Tube for light detection

IHEP (Yang), Naples (Fiorillo, Rossi), LNGS (Razeto), Princeton (Galbiati, Rossi), UCDavis (Pantic), UCLA (Wang), WIS (Breskin)

Felicia Barbato	Graduate Student (Naples)
Alden Fan,	Graduate Student (UCLA)
George Korga,	Electronics engineer (LNGS, Houston Univ.)
Alexey Lyashenko,	Assistant Researcher (UCLA)
Yixiong Meng,	Graduate Student (UCLA)
Emilija Pantic *,	Ass. Researcher (UCLA), UC Davis (Jan 2014)
Yury Savorov,	Postdoc (UCLA)
Artin Teymourian,	Postdoc (UCLA)
Yi Wang,	Graduate Student (IHEP Beijing)

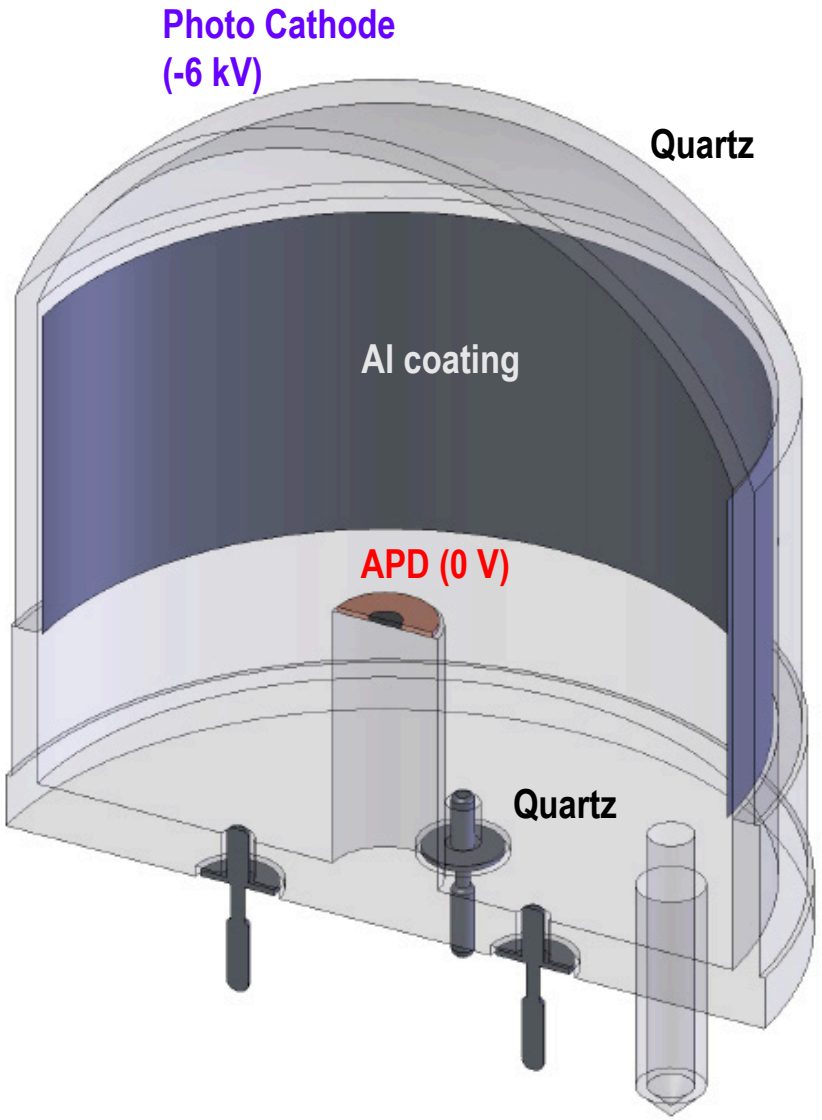
Outline

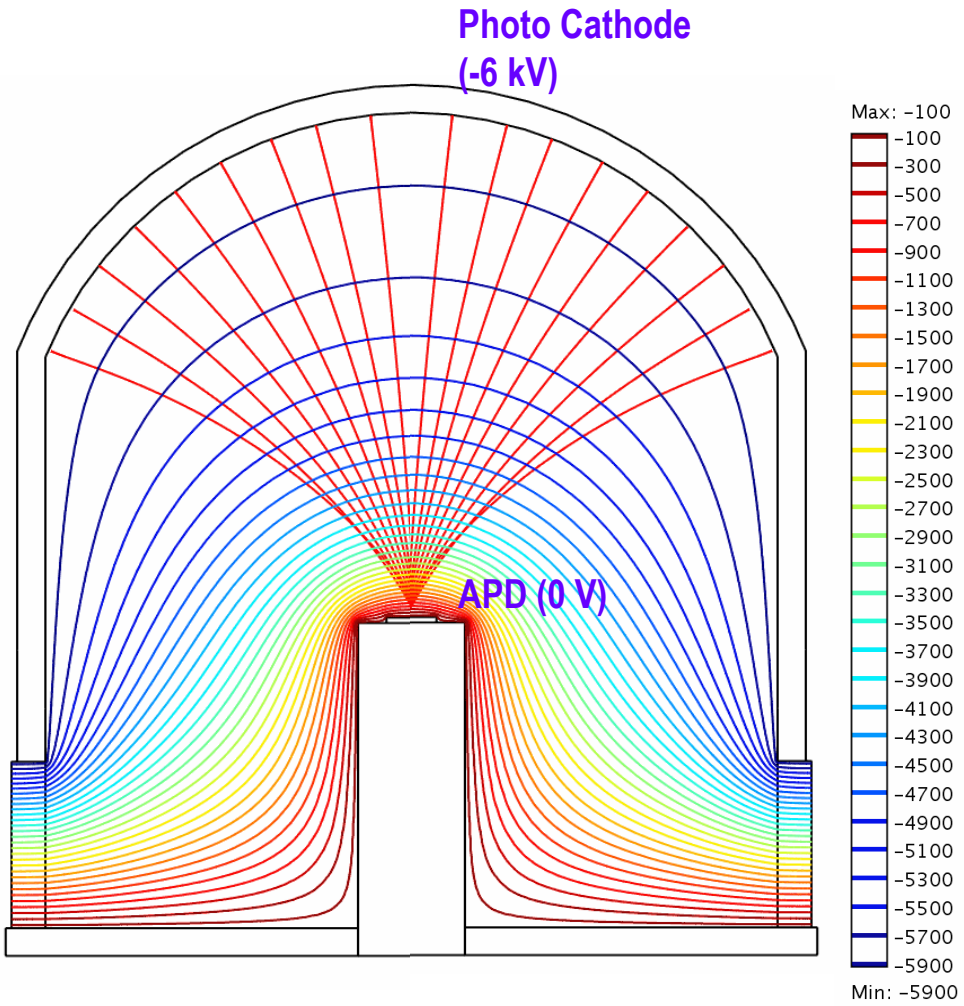
- Brief Information about “QUPID”
- New Developments on “SiGHT”
- Activities at UCLA

No Results within this report,

“as there isn’t any in SiGHT yet!”

QUPID Concept: 2007 Arisaka, Wang





UCLA/Hamamatsu Joint US Patent No. 8080806

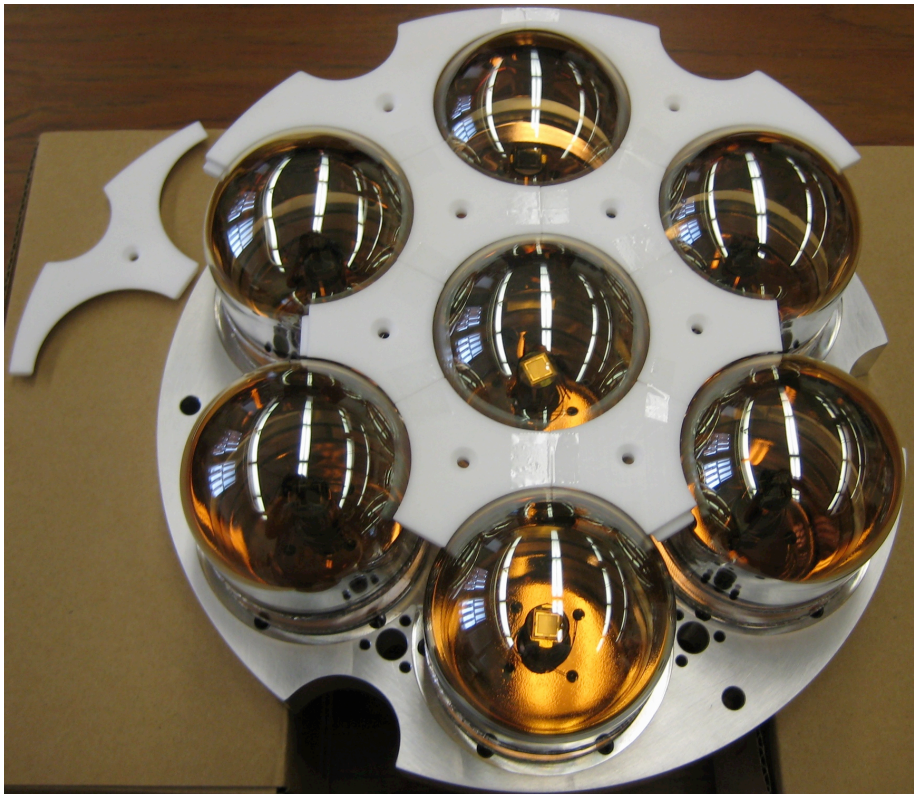
QUPID R&D funded by NSF MAX grant to UCLA through Princeton, NSF base and DOE base support

Publications related to QUPID:

Status of QUPID, a novel photosensor for noble liquid detectors, *Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment,Volume 695, 11 December 2012, Pages 121-124*

Characterization of the QUartz Photon Intensifying Detector (QUPID) for noble liquid detectors, *Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment,Volume 654, Issue 1, 21 October 2011, Pages 184-195*

QUPID, a single photon sensor for extremely low radioactivity A. *Nuclear Instruments and Methods in Physics Research A 623 (2010) 270–272*



Two Emails Triggered the SiGHT Effort

- August 16, 2012 H. Wang to Ardavan Ghassemi (Hamamatsu)
- August 26, 2012 Ardavan Ghassemi's Replied to H. Wang

Dear Tom and Ardavan, (Email Dated 8/16/2012)

It was a real pleasure to have you on UCLA campus and discuss some of the businesses related to photo-sensors.

This is just a reminder and on the record that I would like to have some information about the status at Hamamatsu on our joint patented QUPID effort. The patent number is US 8080806 (attached).

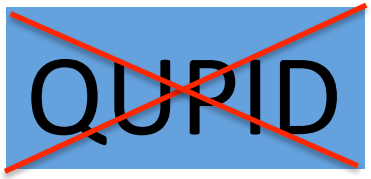
I cc to my colleague Prof. Katsushi Arisaka since we are both on the patent and he has been the sole contact and main force pushing for this work. ……..

This is a key product which should revolutionize the future low background experiment and our venture has been more than 5 years. I would like to have some conclusion or a clear idea how to proceed. So I can make plans related to such R&D effort……..

Any information on how we should proceed officially would be greatly appreciated.

Best,
Hanguo

Hamamatsu Reply (Dated 8/26/2012)



Dear Hanguo,

Hamamatsu Japan commented that they've stopped the development effort of QUPID. They promised to provide a report on the QUPID development effort in a month or two. I'll send it to you after receiving it from them. Please let me know if you have any question or comment in this regard or if I can help you with anything else.

Ardavan Ghassemi

Applications/Sales Specialist for Scientific Projects
(P) 908.252.7632
http://sales.hamamatsu.com

Main Issues with QUPID: Yield!

- Operating Voltage too high (>6kV)
- Vacuum Seal Reliability
- Amount of Indium Used (~9g)
- Long Term Stability
- Yield is low!
- Hamamatsu stopped the effort

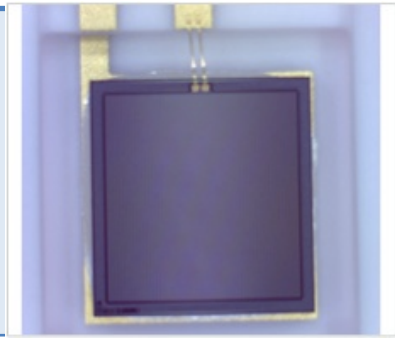
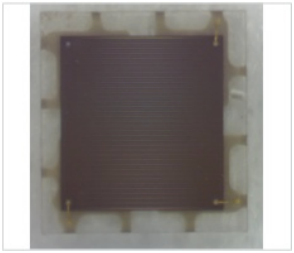
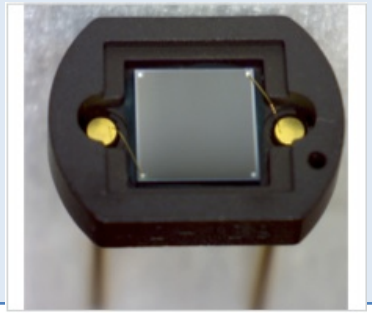
SiGHT using SiPM instead of APD

- Much lower operating voltage (HV ~ 2kV)
- Minimum Amount of Indium for Seal (<20mg)
- 100% Fused Silica Profile
- High QE (! -> WIS Development system)
- Eliminate Most Metal Electrical FTs
- Assembly in Vacuum (no PC process after assembly) (potentially high yield)

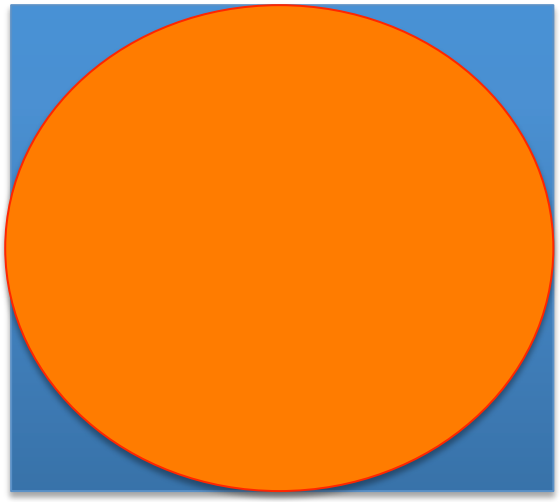
Development Steps

- Photoelectron trajectory modeling to define fused Silica profile
- Evaporation Coating Procedure
- Indium vacuum seal procedure
- High QE PC Procedure (WIS, UCLA)
- Low-T PC development
- Choice of SiPM (performance study: Naples)
- Full Assembly System Design Study
- QA for large scale production

SiPM samples for first prove of principle demonstration

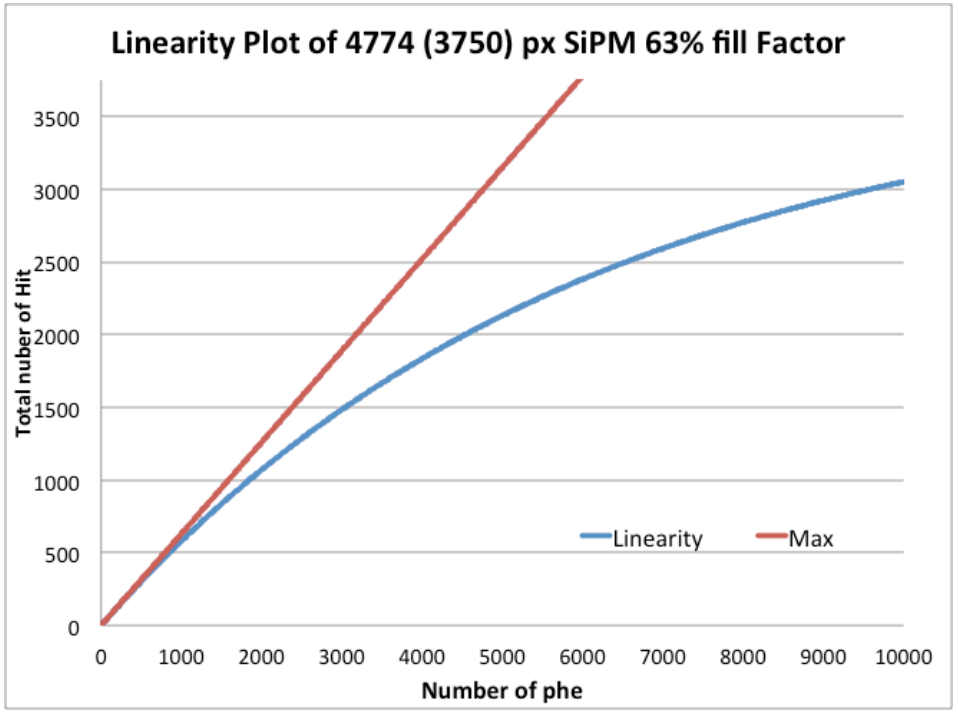
SiPMs	Active area	# pixels	Fill area	Gain	Samples being tested.
Hamamatsu S10362-33-025C SPL ceramic package no coating	$3x3mm^2$	14400	30.8%	2.75×10^5	
Sensl MicroFM-30035-SMT with epoxy(?)	$3x3mm^2$	4774	63%	2.3×10^6	
Sensl MicroSM-30035-X13-NE ceramic package no epoxy	$3x3mm^2$	4774	63%	2.3×10^6	

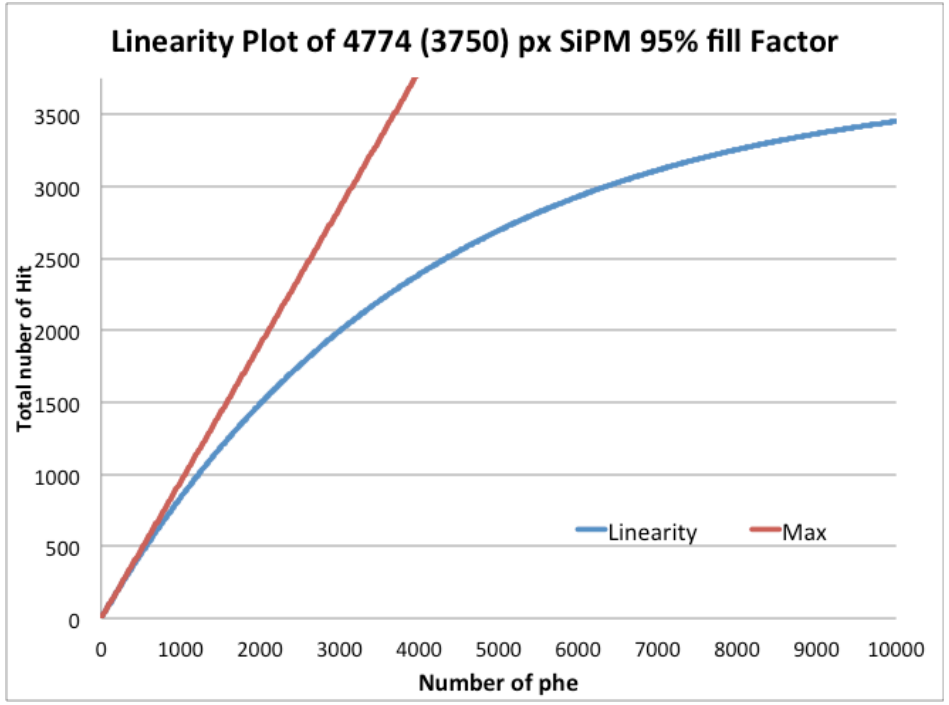
Linearity the Fan's Equation (QE not considered)



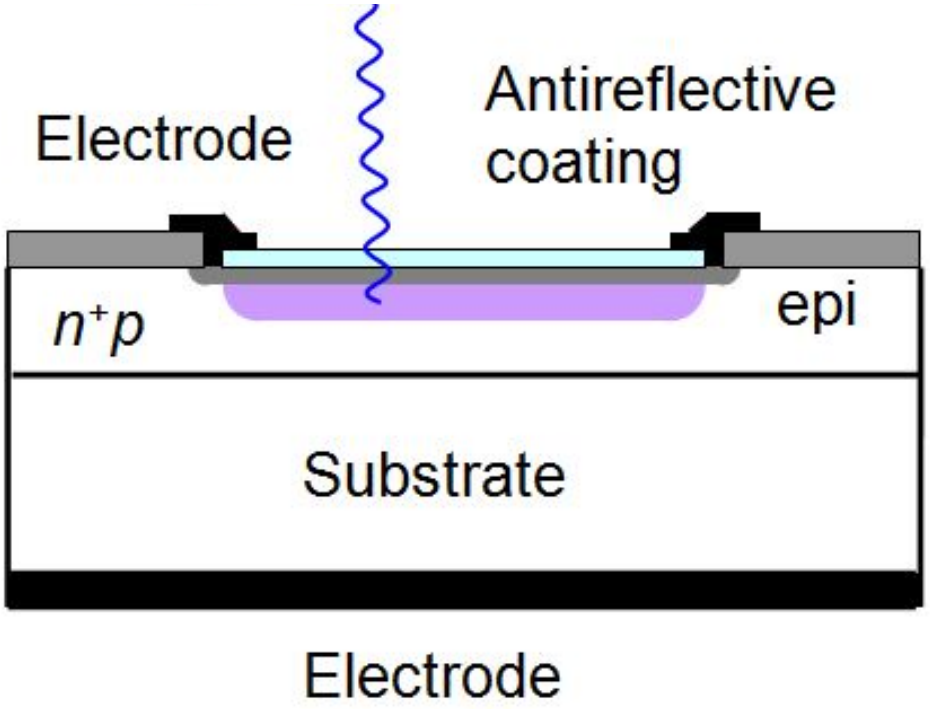
$$n = N\left[1 - \left(1 - \frac{1}{N}\right)^{\lambda m}\right] \approx N\left(1 - e^{-\lambda m/N}\right)$$

n. Total number of cells have at least one hit
N. Total number of pixels (π/4)
m. Number of original photoelectrons
λ. Fill factor





Front Illuminated



Back Illuminated

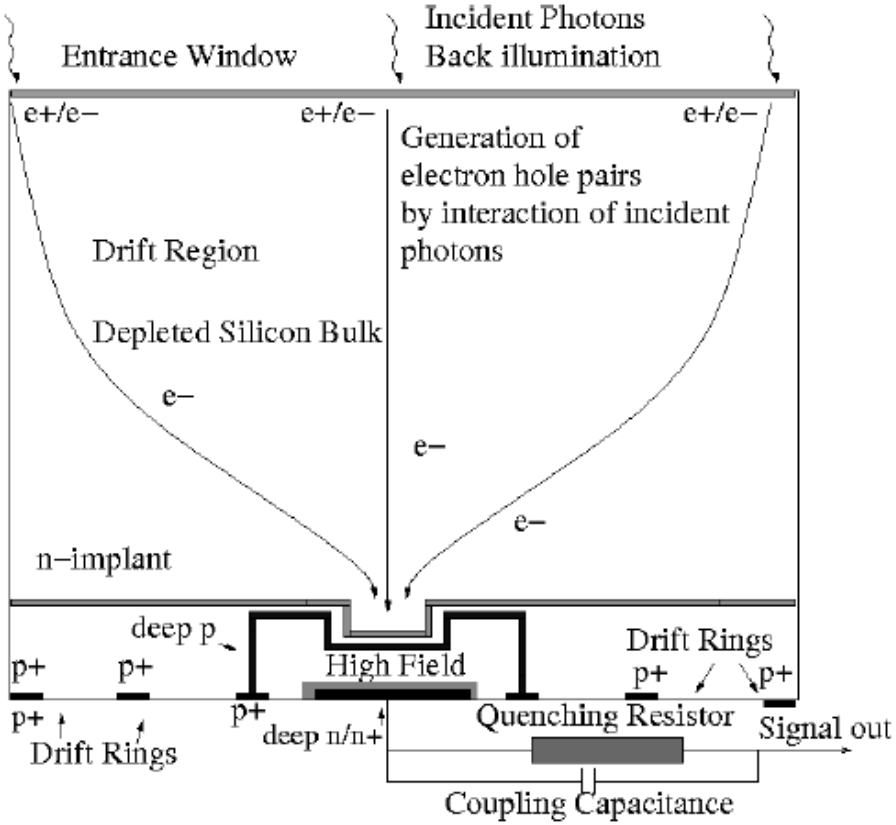


Fig. 1. Schematic view of a single cell of the BID SiPM concept

Compare fill factor and Geiger region of front and back illuminated SiPM

Effective Geiger mode area is very small

Christine Merck et. al. http://www.hll.mpg.de/07_publication/2006/N42-3.pdf

Back Illuminated Drift SiPM

QE ~80%, Fill Factor ~100%, Very low Dark Count (~kHz at 300K)

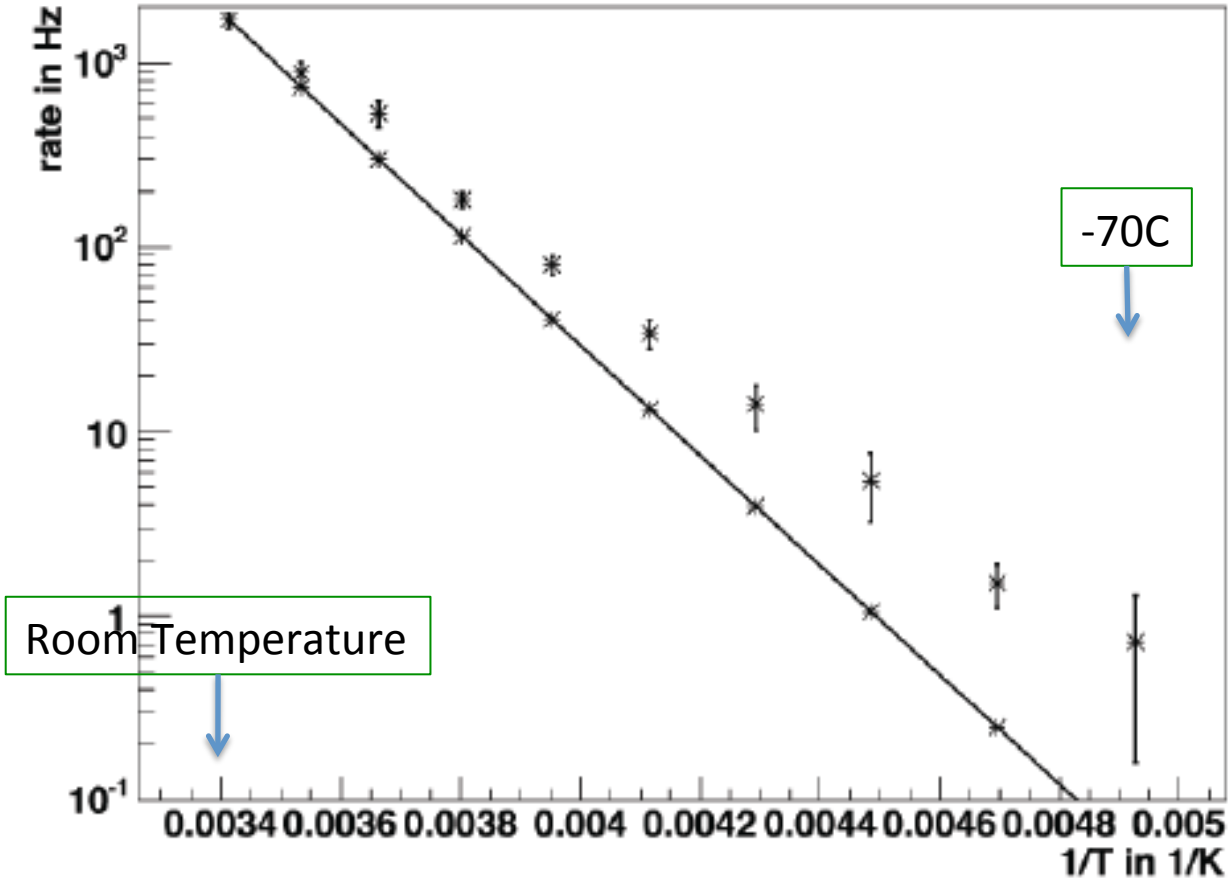
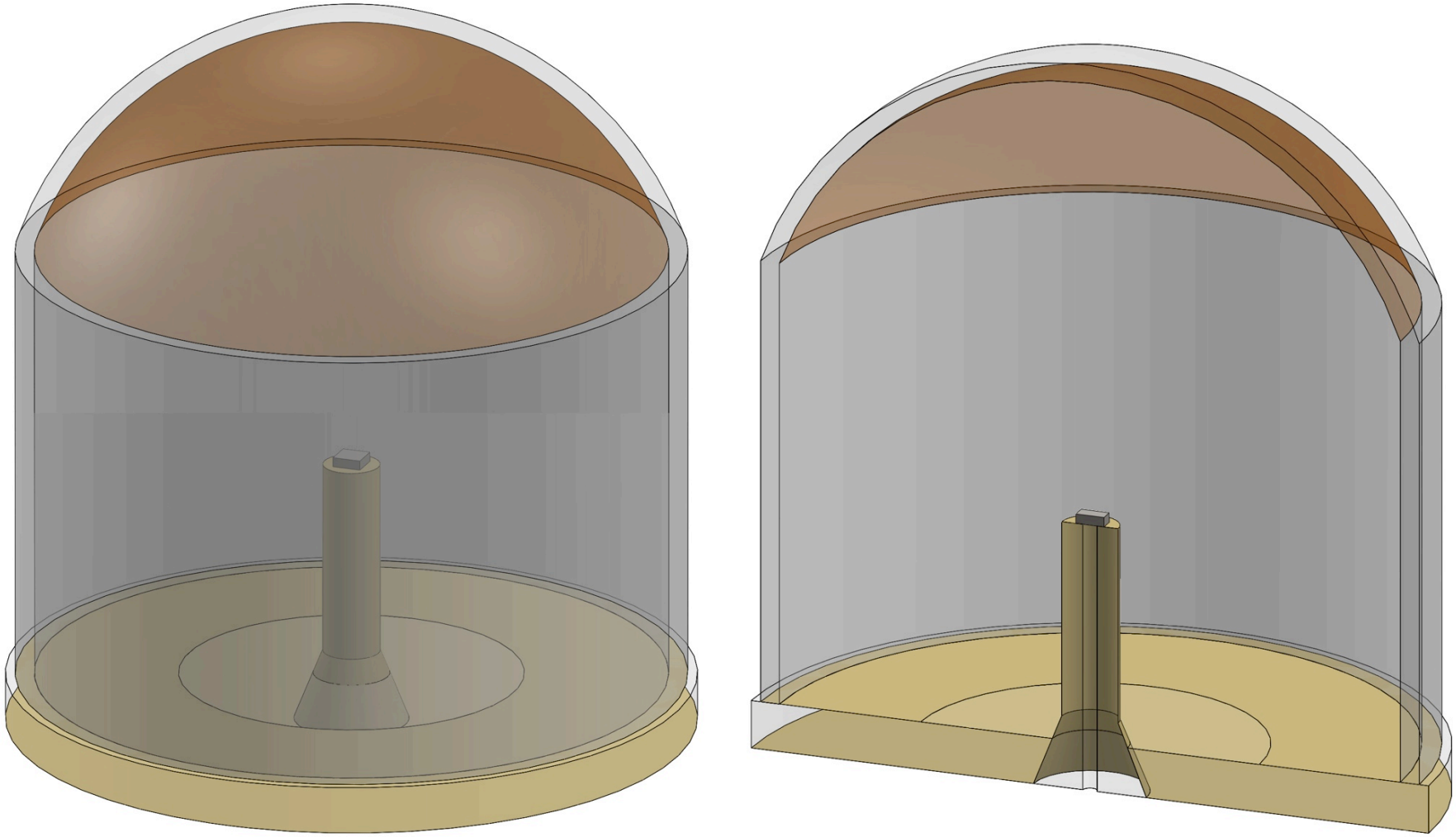


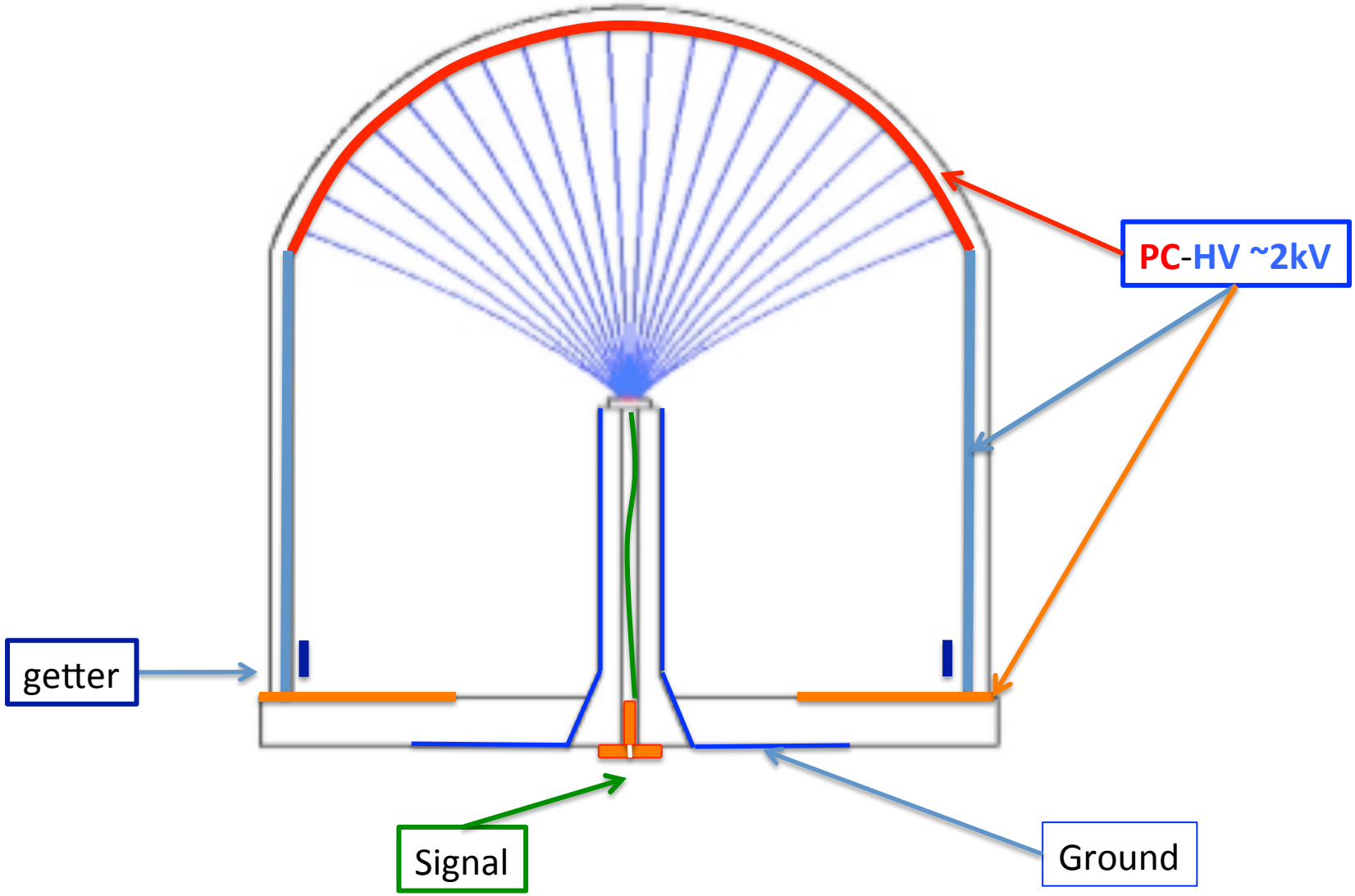
Fig. 2. Comparison of dark rate measured at ca. 10% overbias and theoretically calculated values (Shockley-Read-Hall Generation) plotted as line

Christine Merck et. al. http://www.hll.mpg.de/07_publication/2006/N42-3.pdf

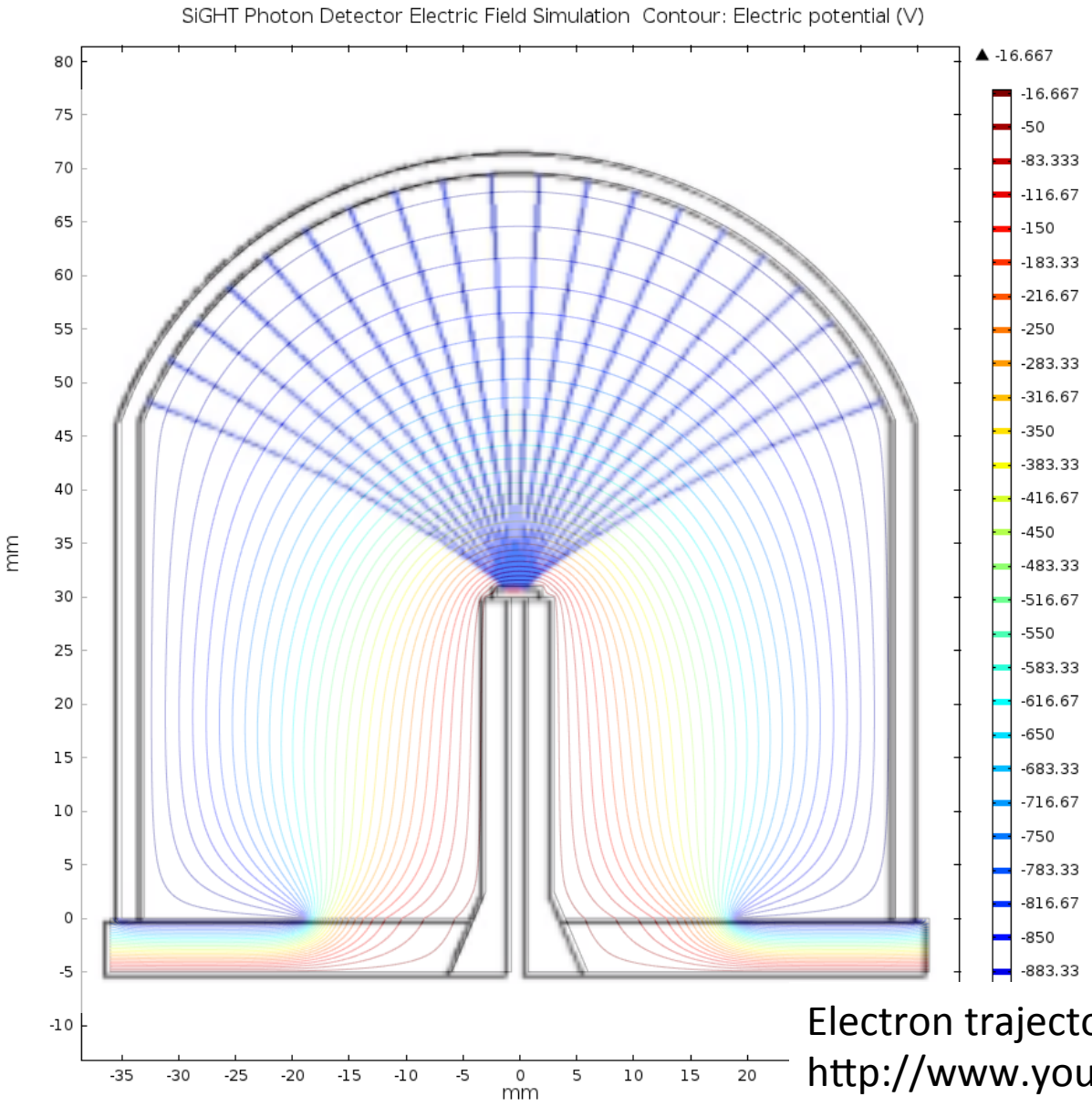
Sketch of the SiGHT photosensor



SiGHT Electrical arrangements



Electron Tracing ~~Being~~ Studied

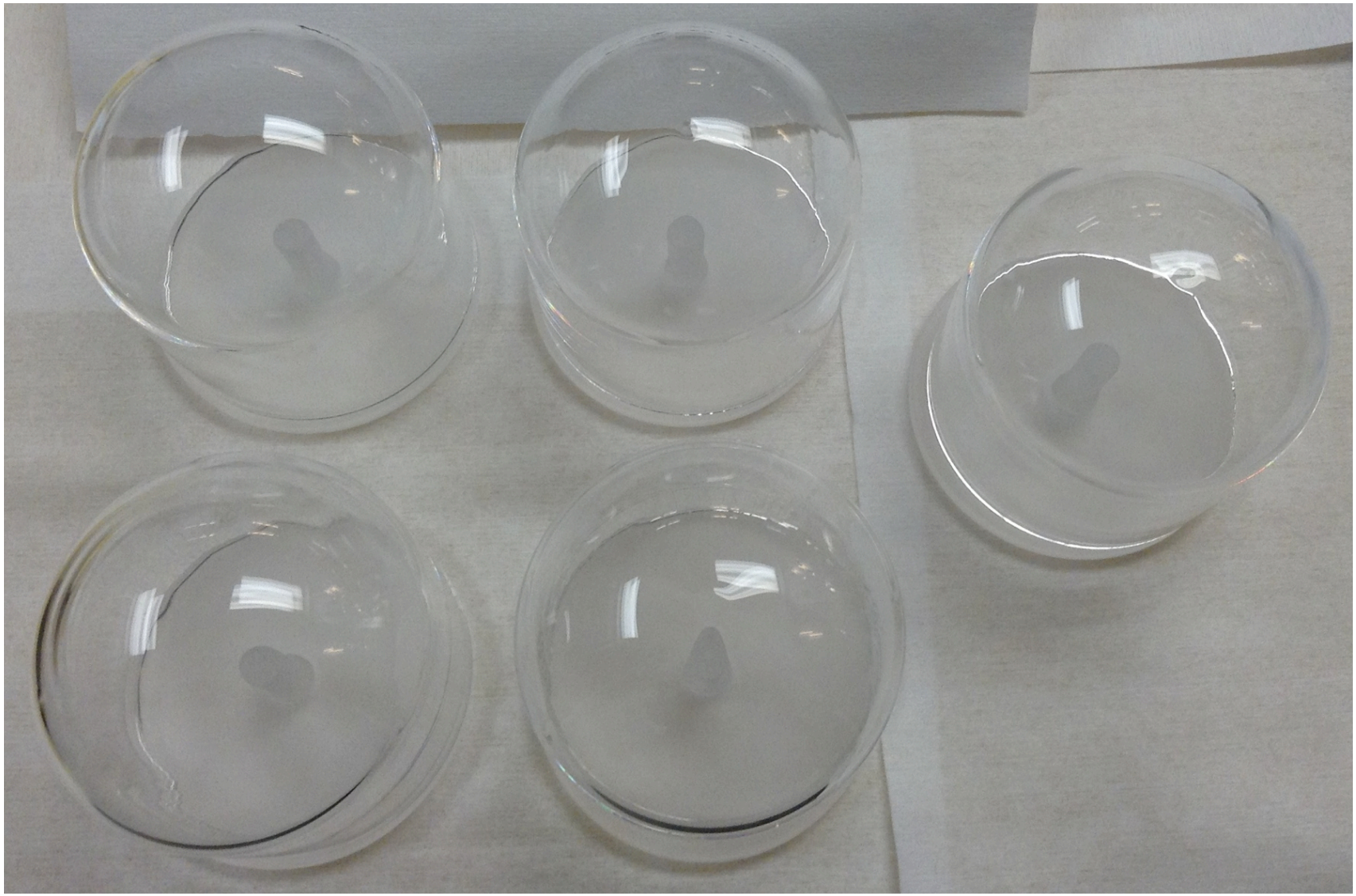


Map out Field Range (1kV-2kV)
Full Field definition (no external influences)
Prevent perfect focusing
Low Total Potential difference

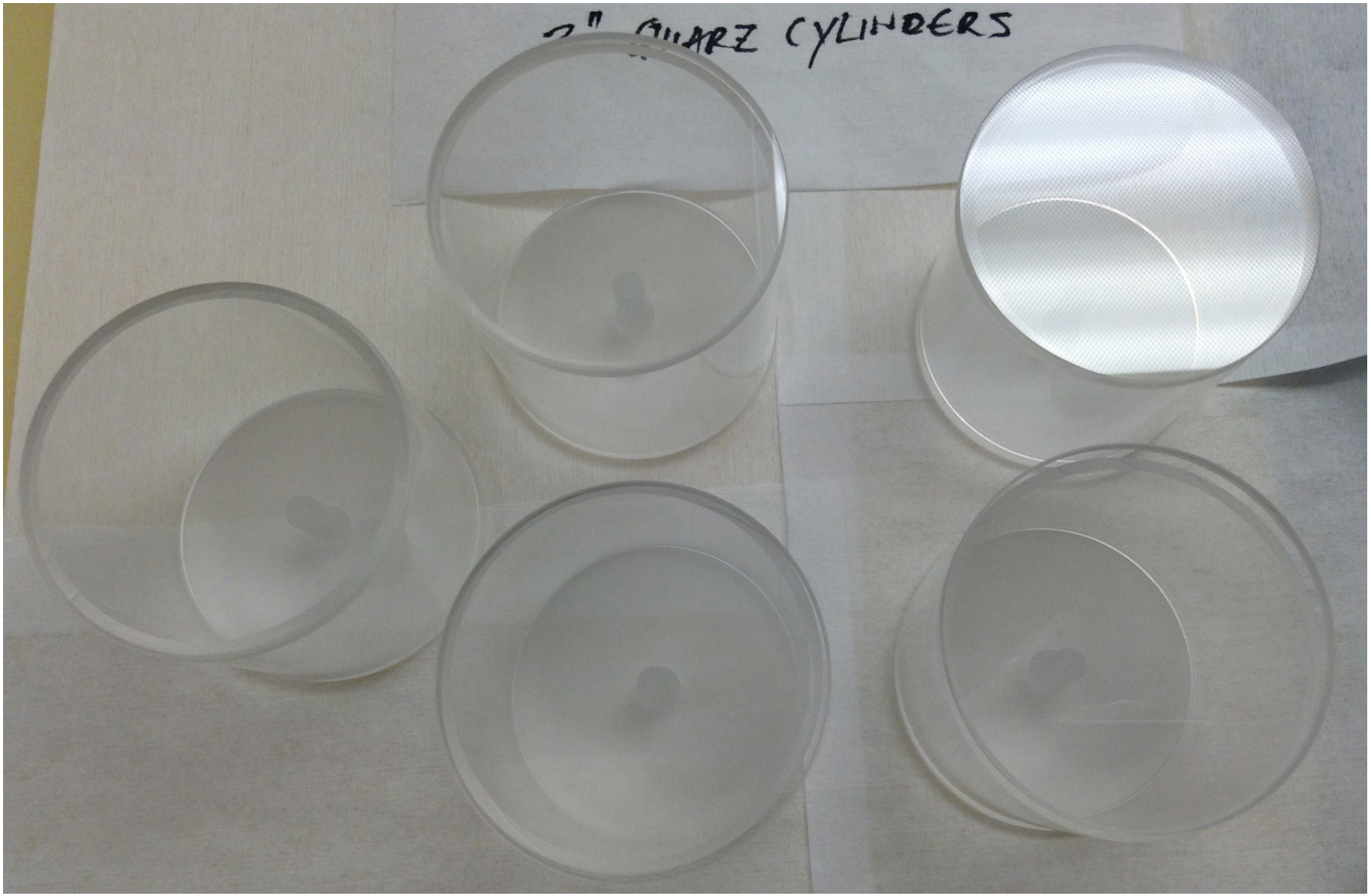
Static Field eq-V Lines

Electron trajectories at 1kV can be found here:
http://www.youtube.com/watch?v=5QWAKf2-e6k

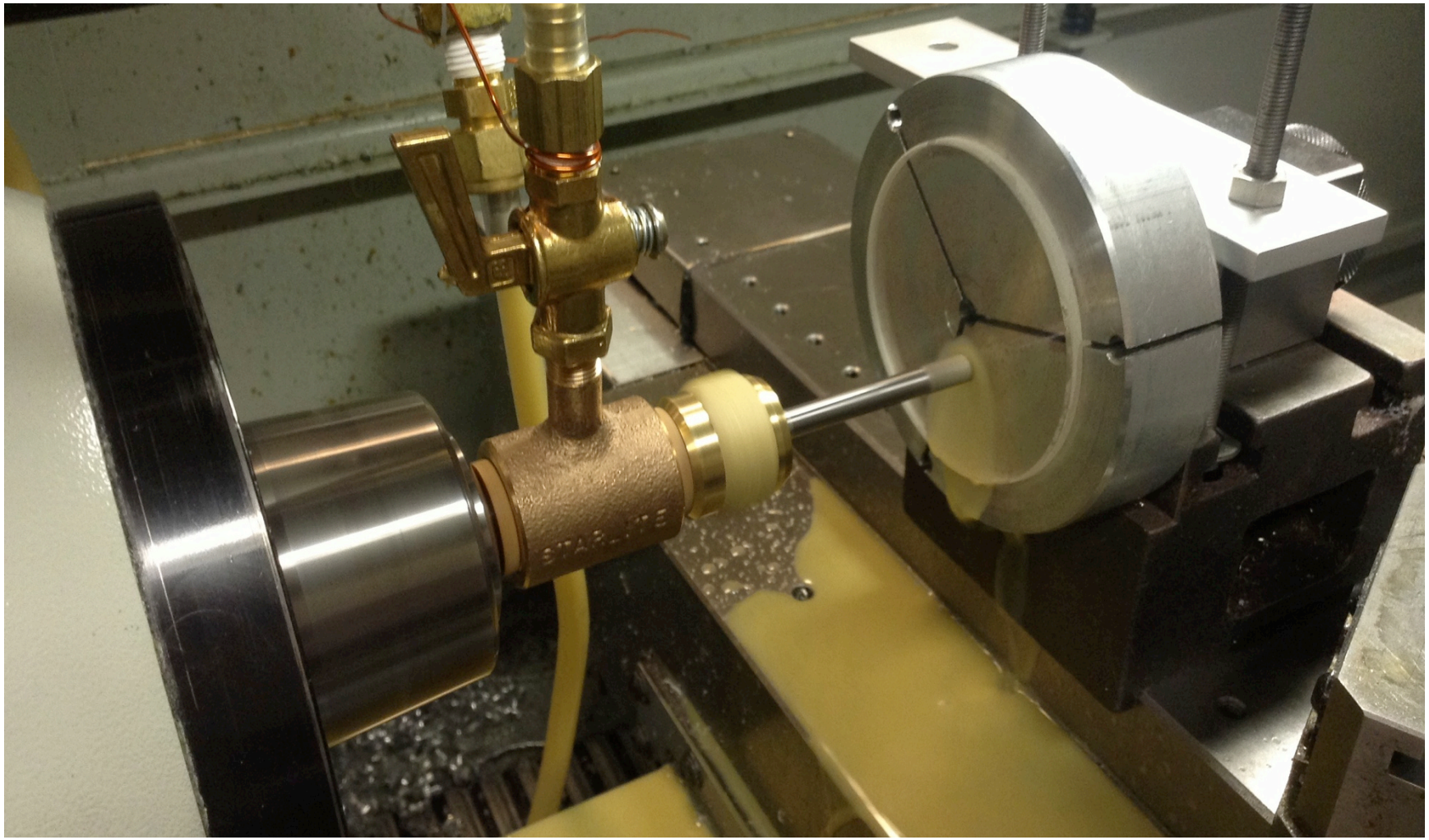
SiGHT Fused Silica Profile 3” (4”)
5 sets Dome + pillar+ baseplate



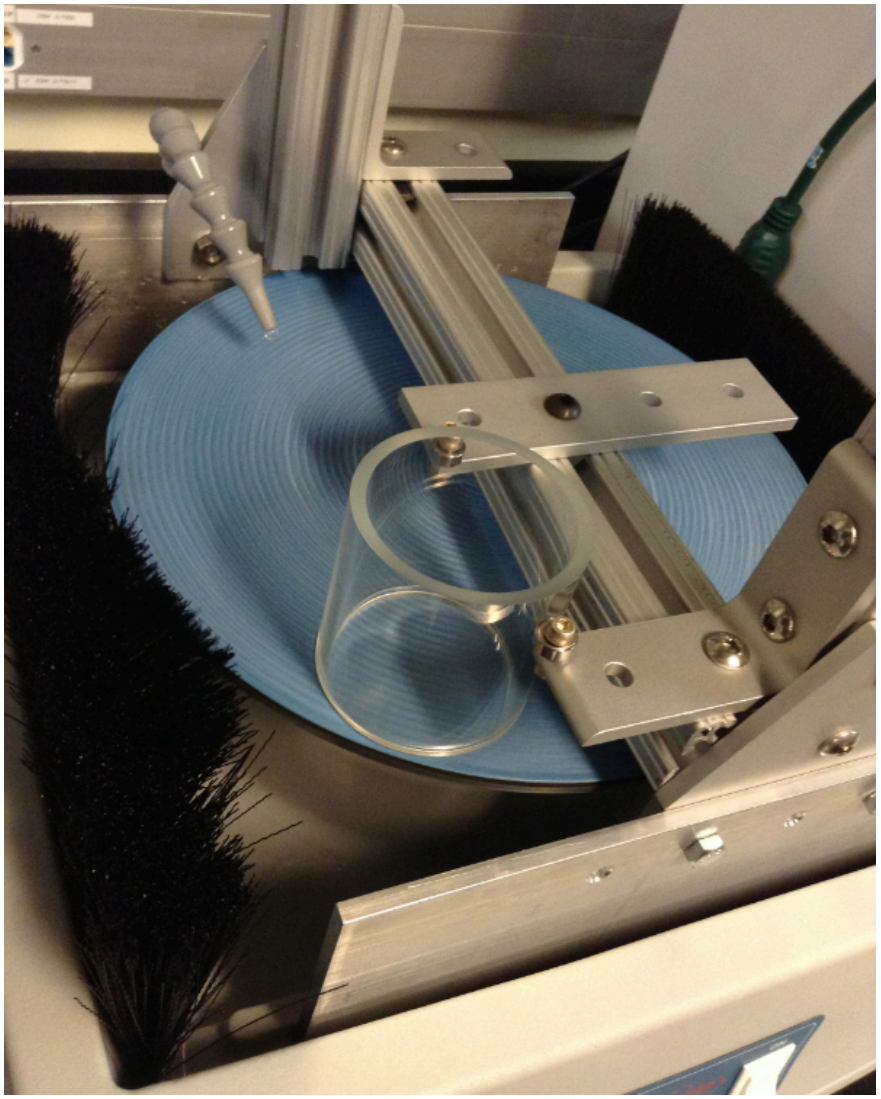
Indium Vacuum Seal Study with Quartz Cylinders

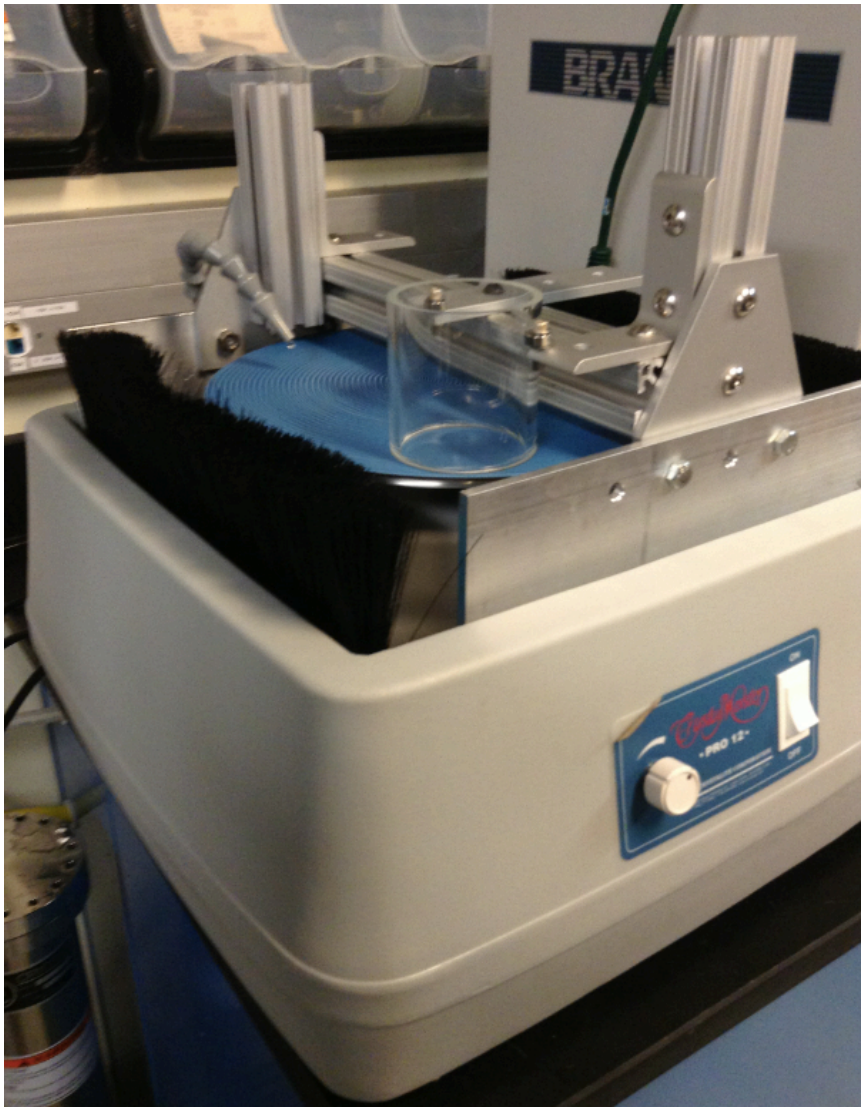


CNC Set Up for Quartz Drilling



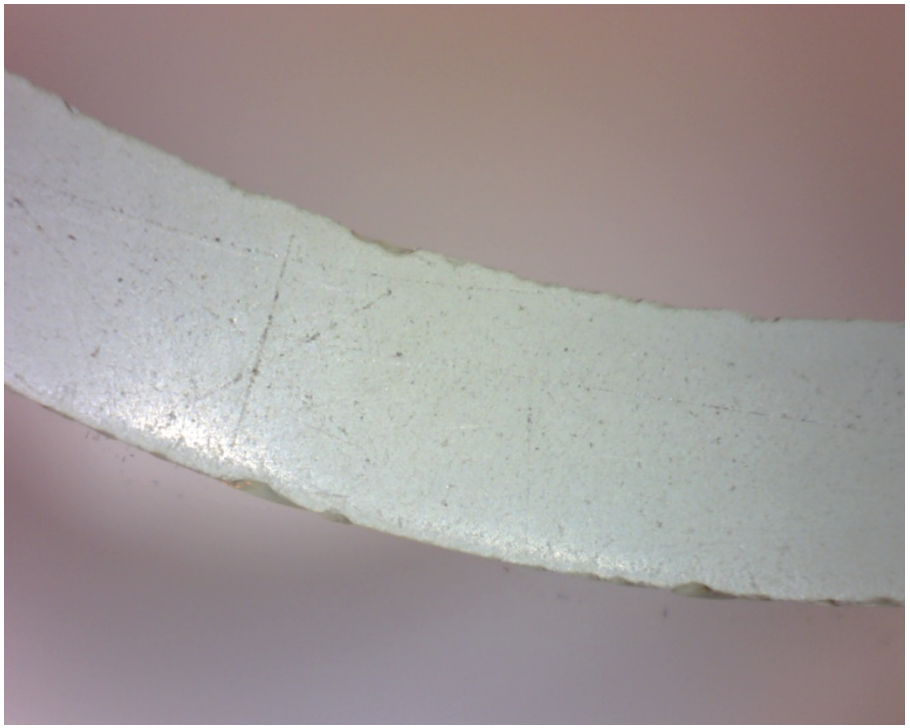
Lapping Machine
to prepare flat surface for Indium Seal



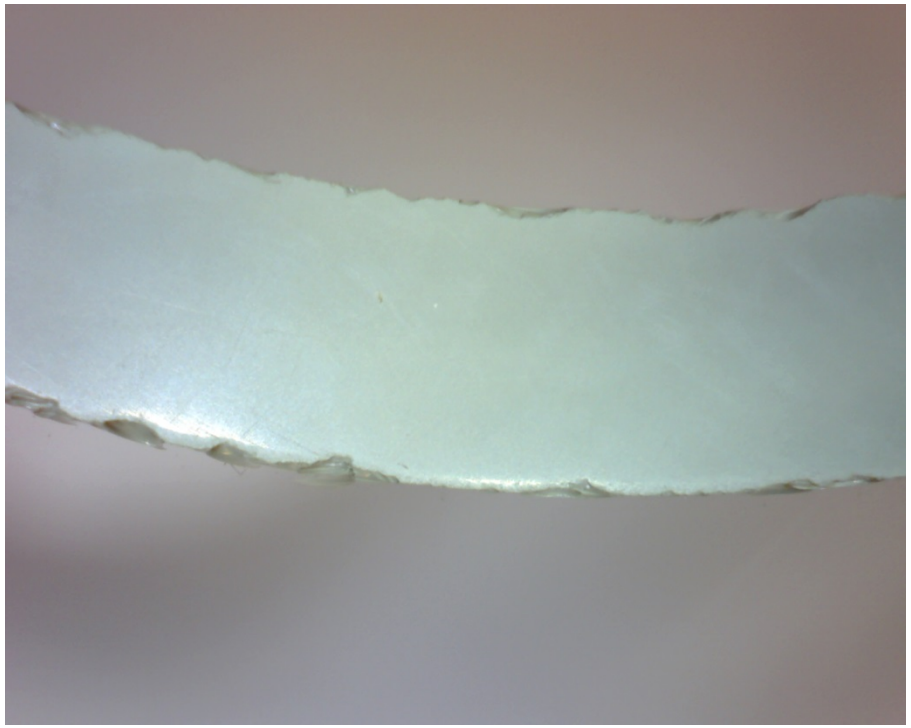


Fused Silica Cylinder Surface polishing

Preparing for Indium Seal

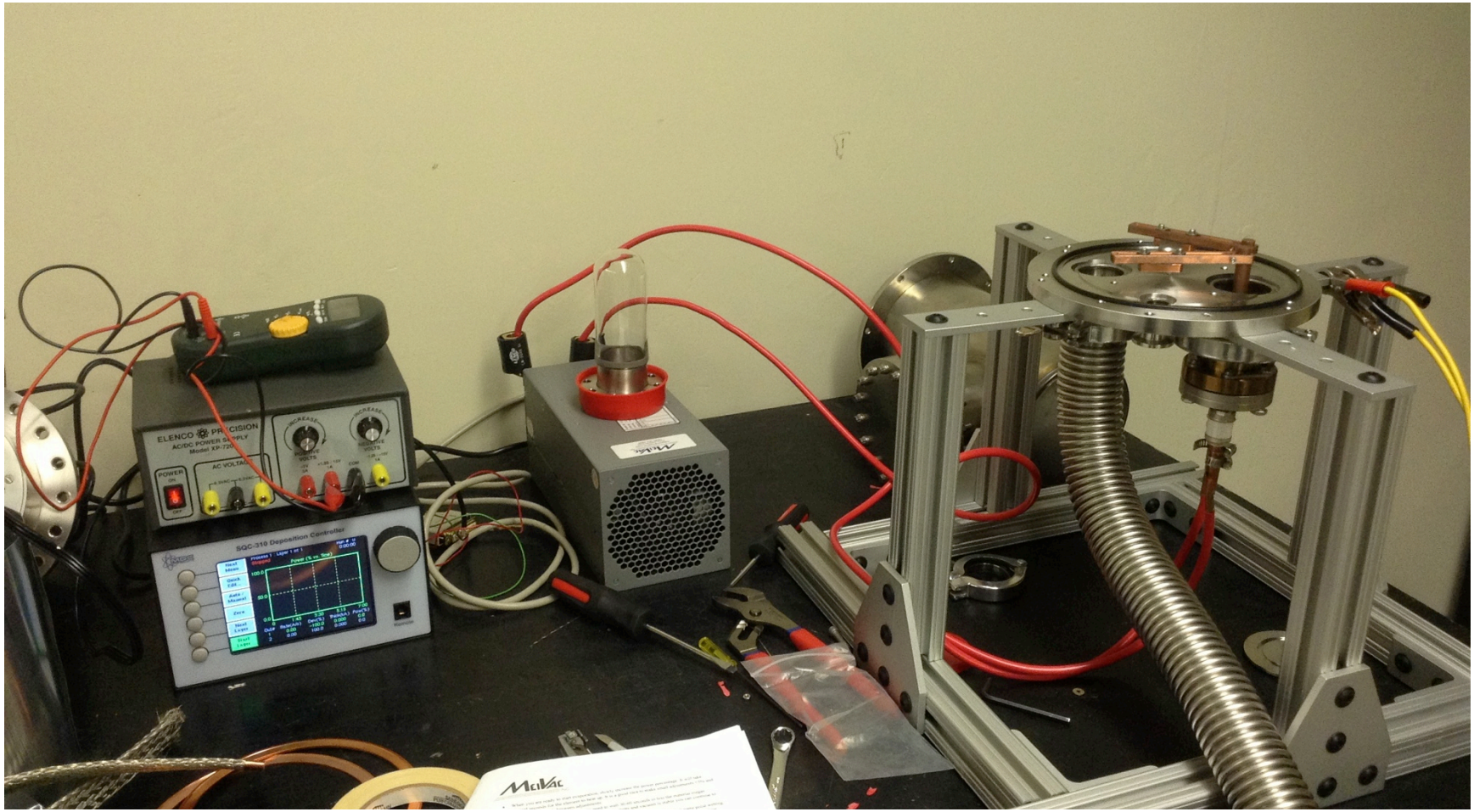


After Hand Polishing
Up to 240 grit

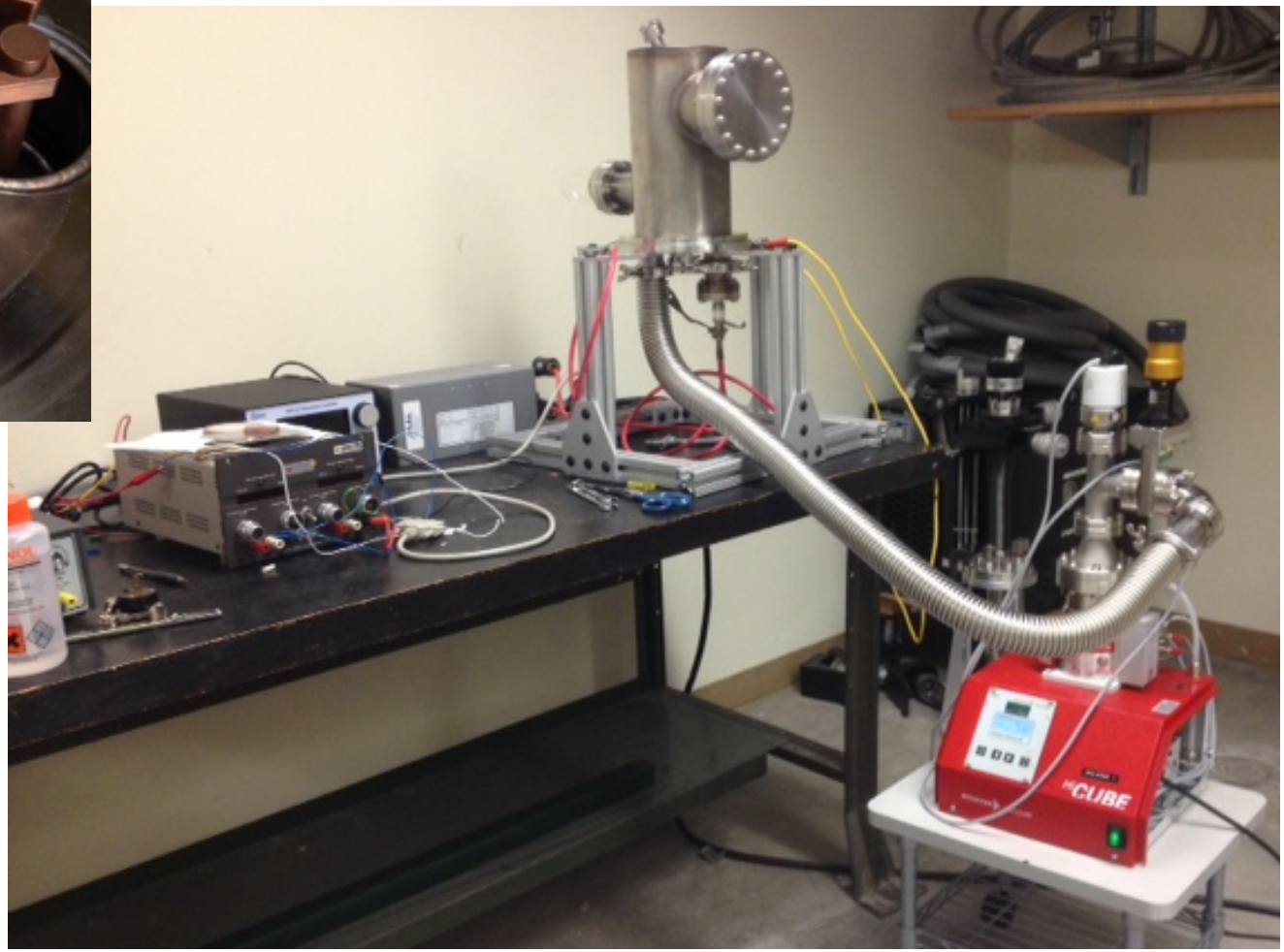


After Lapping
30min 1500 grit

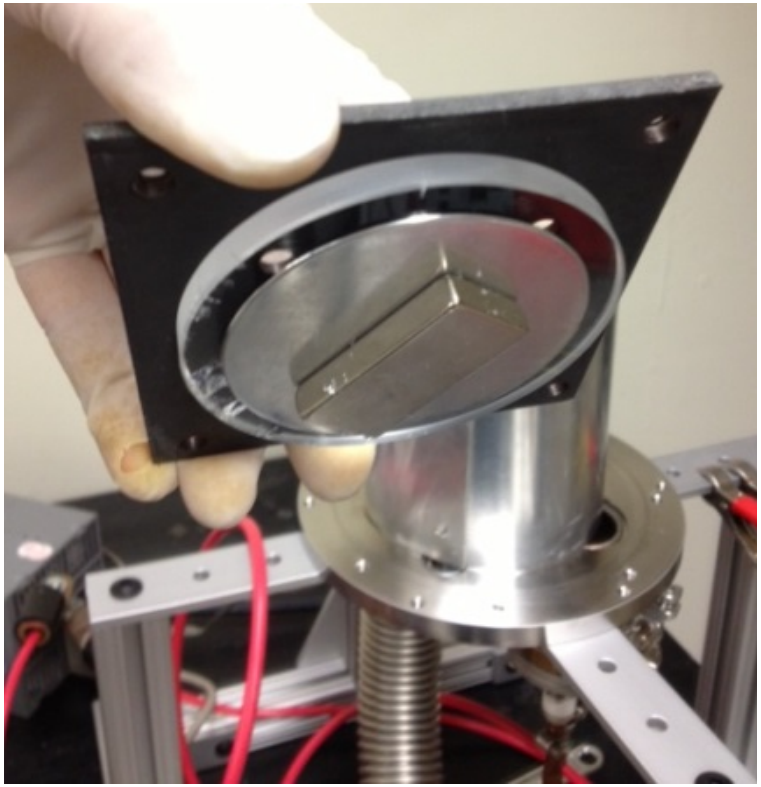
Metal Deposition System (thermal)

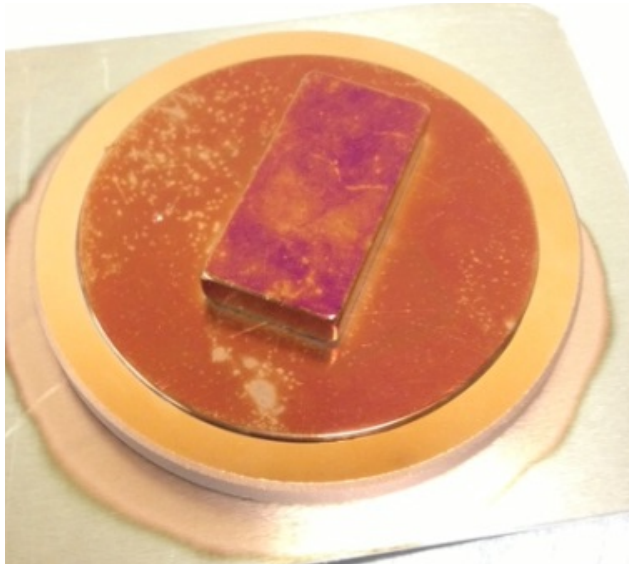


Metal Coating System
will upgrade to integrate into the full system



Now all coating are done in house:
Chromium, Copper, Gold, CsI, and Indium coating
Indium seal procedure tested





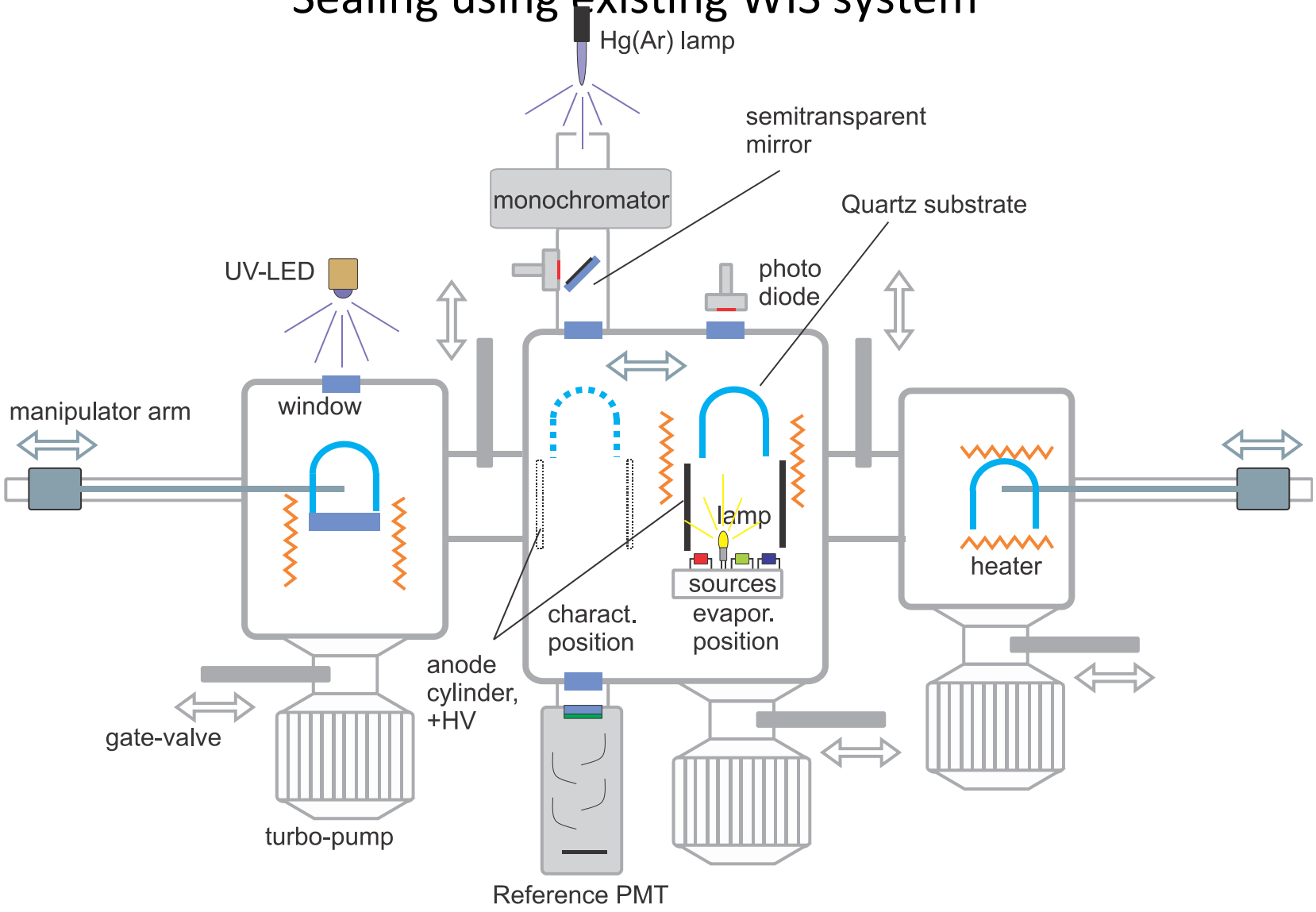
Indium Seal Tested!

- Chromium, Copper, Indium Vacuum Deposition
- No Air contact after coating
- Warm Seal with Heat in Argon gas with heater
- Leak tested after each LN2 cooling cycle up to ten times.
- Final seal using Induction heating in vacuum (being studied)

Prove of principle Sample

- While waiting foe the WIS system, Using CsI photo cathode to prove the concept
- Sample assembly in Vacuum system from the start
- Getter activation in vacuum before assembly
- Test every assembly step before first assembly try

First prototype Photocathode Production, Characterization and Sealing using existing WIS system

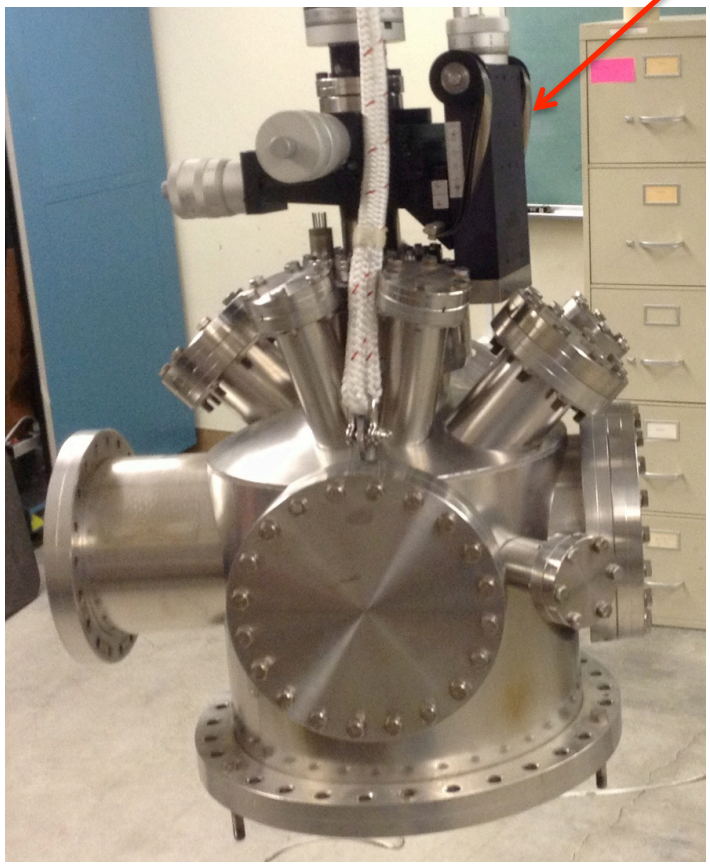


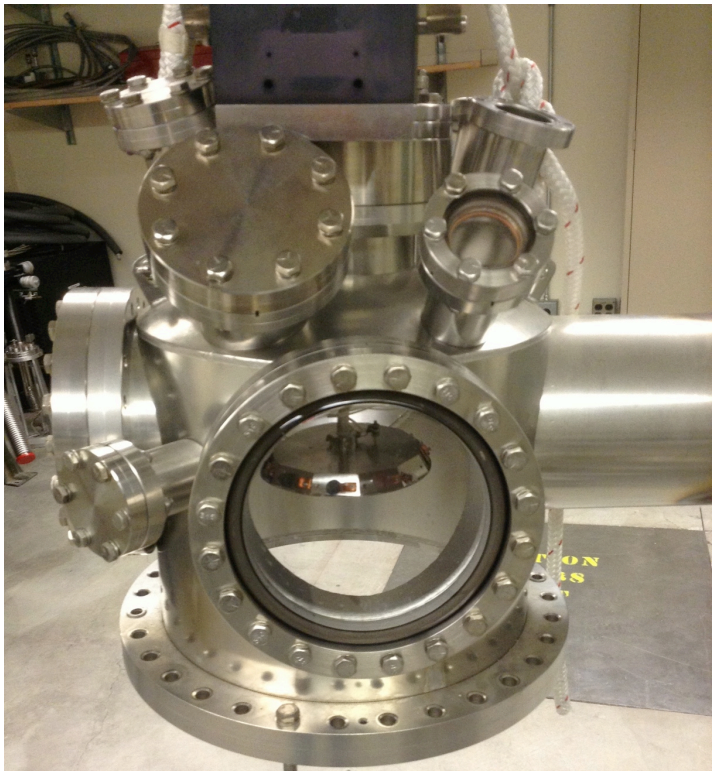
WIS Photo-sensor development system being shipped to UCLA

Shipment contents: 3-chamber deposition and transfer setup mounted on a metal stand, 2 electronic racks, 4 boxes with spare parts and documentation

Parts for First SiGHT Sample Vacuum Assembly System

Bellow Sealed Motion feedthrough





Summary

- BID SiPM is the way to go ~80% QE, ~100% fill factor
- Overall QE >35% possible
- Key Indium Seal procedure Tested.
- In Vacuum Assembly procedure being developed
- Waiting for WIS PC development system
- Will Request serious funding to demonstrate production feasibility in house
- QA procedure to be developed