LIPSS Searches with the JLab Free Electron Laser

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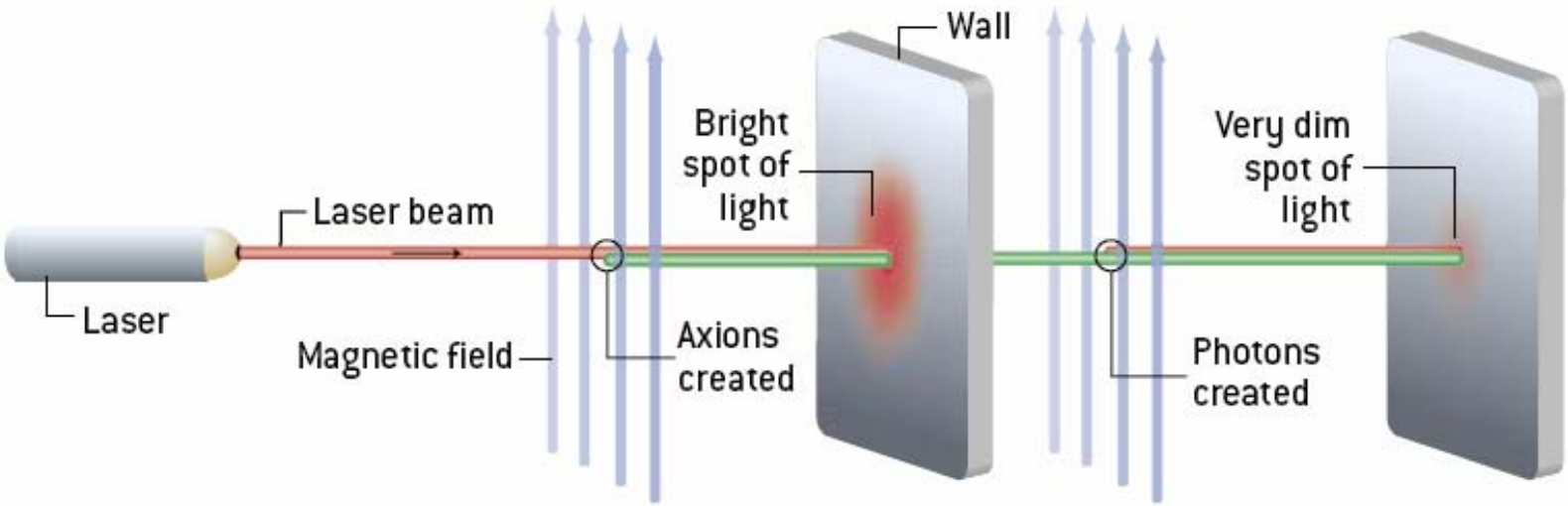
for the LIPSS Collaboration

5th Patras Workshop
Durham, England
14-July-09

`Light Shining Through a Wall'

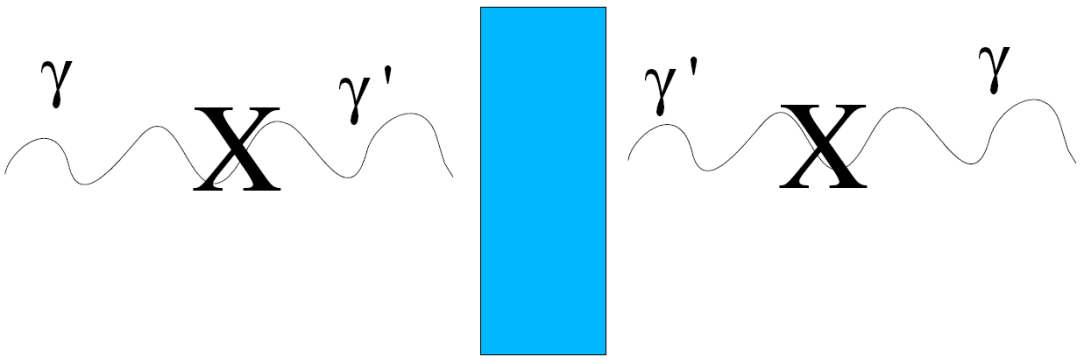
- Sikivie (1983); Ansel'm (1985); Van Bibber et al (1987)



LIGHT BEAM experiment that would confirm the existence of axions passes a laser beam through a strong magnetic field, converting some photons to axions (*green beam*). The axions penetrate a wall before passing through another magnetic field that converts some of the particles back to photons, which form an extremely faint spot on the far wall.

photon regeneration
'light shining through a wall'

(1)

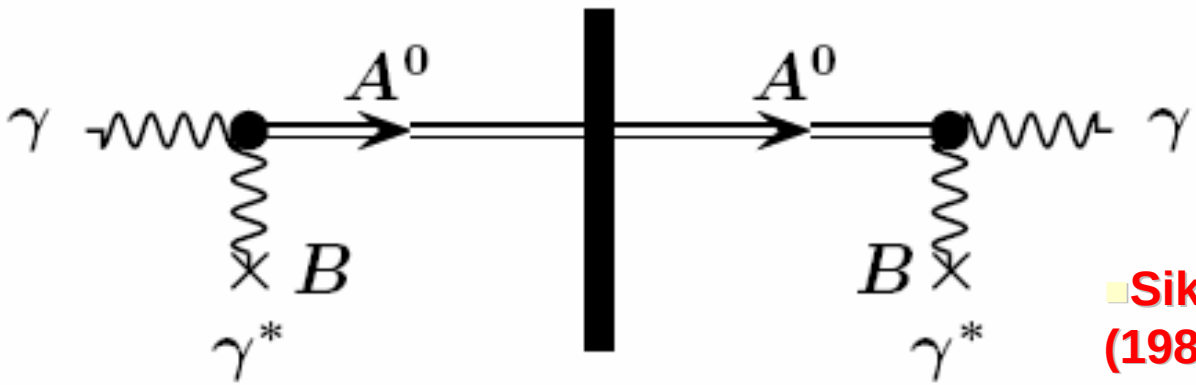


kinetic mixing

no magnetic field needed

hidden sector U(1) search

(2)



coupling to

magnetic field

axions, MCP search

Sikivie (1983); Ansel'm (1985); Van Bibber et al (1987)

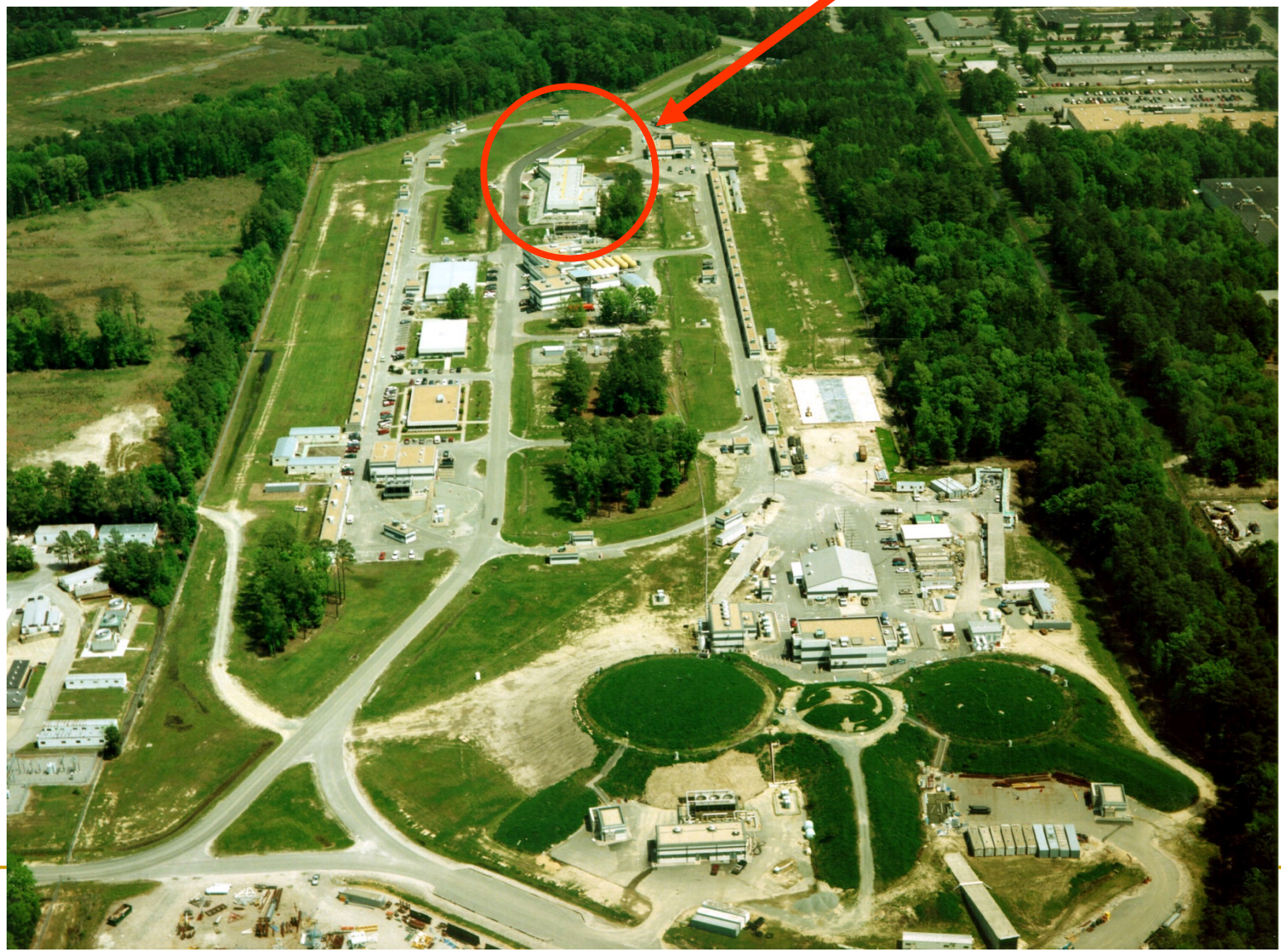
LIPSS recent highlights . . .

- just completed a new experimental run at JLab (June 29 – July 2).
  - pseudoscalar configuration (**E** 'dot' **B**)

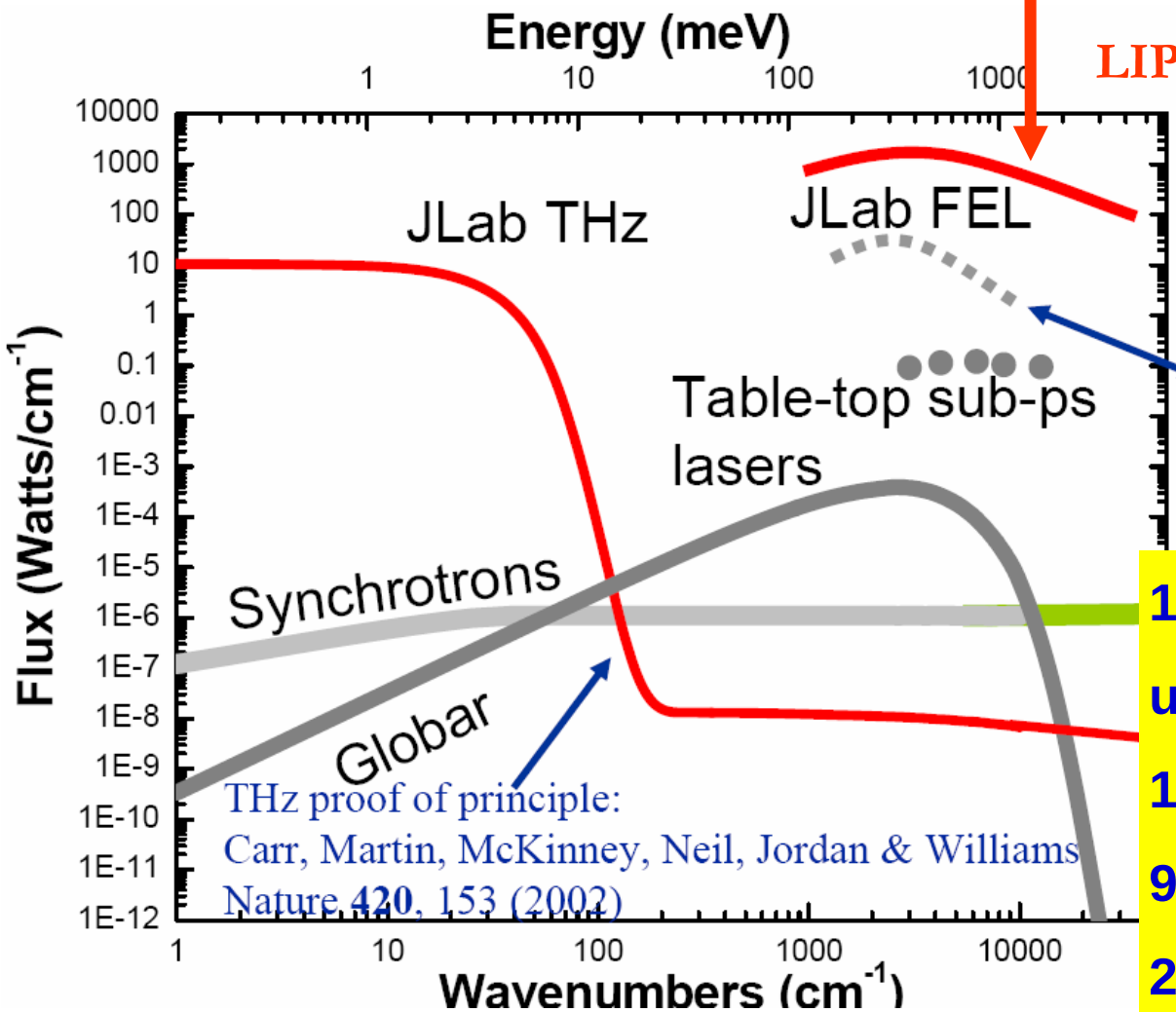
- why?
  - complements scalar data from 2007 (E^2-B^2)
  - new FEL optics
  - **motivation to run at 935 nm from Adler '08 paper**
    - cusp effect at threshold leads to more sensitivity
    - checks for possible form factor dependence of coupling

- microwave cavity experiment in preparation
  - See P. Slocum's talk later in the conference

Jefferson Lab's Free Electron Laser



JLAB FEL spectroscopic range



LIPSS IR run at 935 nm

FEL proof of principle:
Neil et al. Phys. Rev.Letts **84**, 662 (2000)

THz proof of principle:
Carr, Martin, McKinney, Neil, Jordan & Williams
Nature **420**, 153 (2002)

150 fs wide pulses

up to 75 MHz rep rate

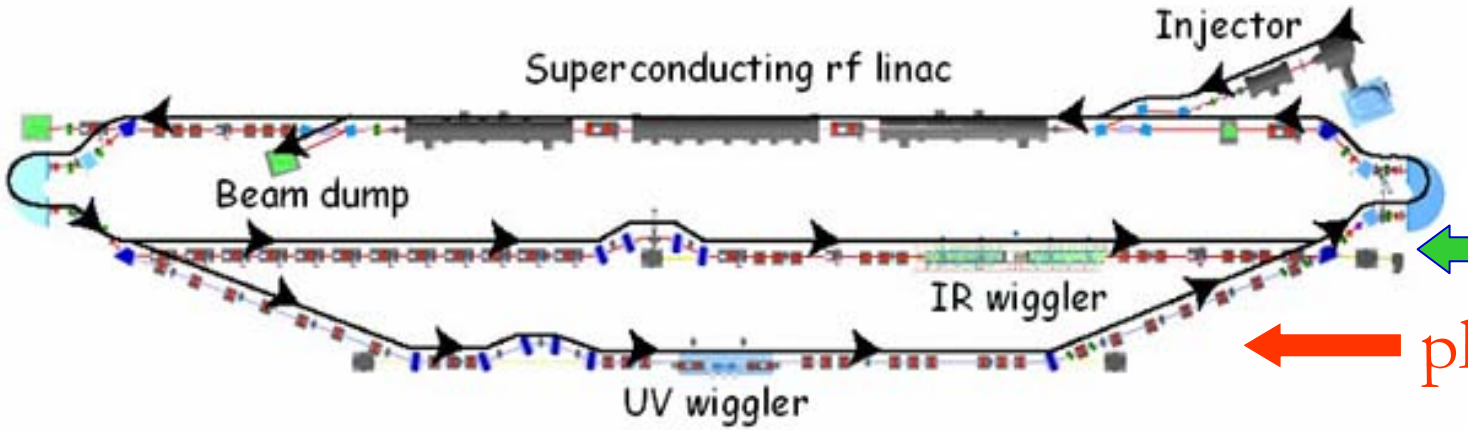
100 % df

935. +/- 005 nm

200 watts avg power

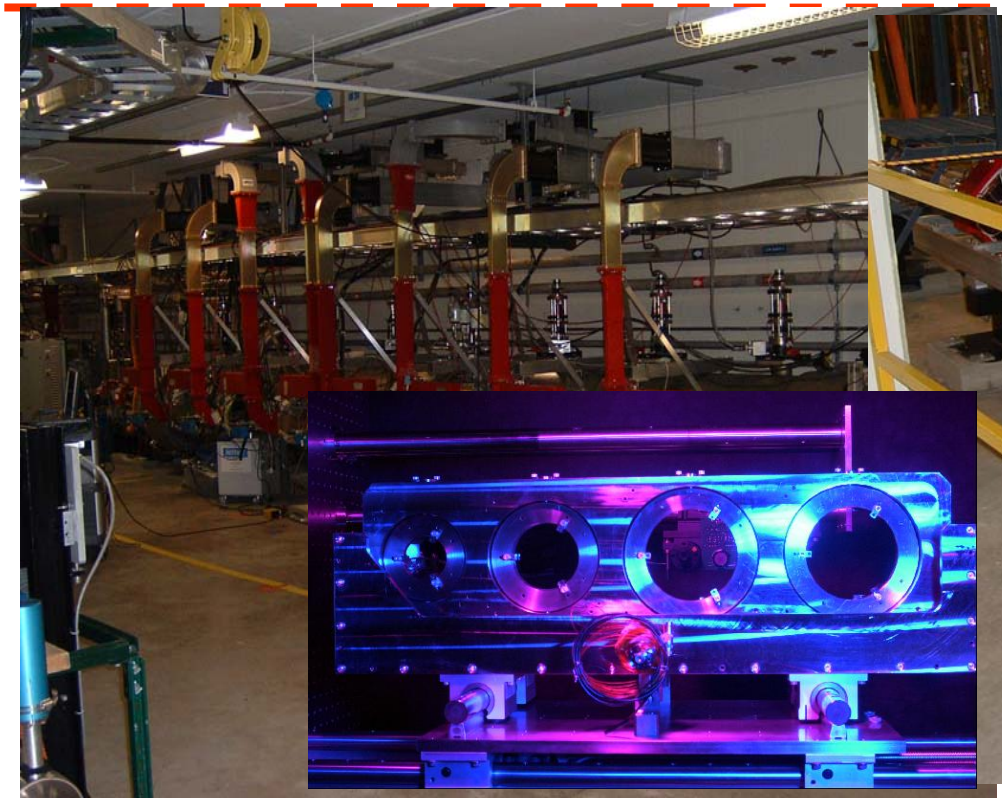
>99% linearly polarized

JLAB FEL: regeneration experiment



current

planned; 2010

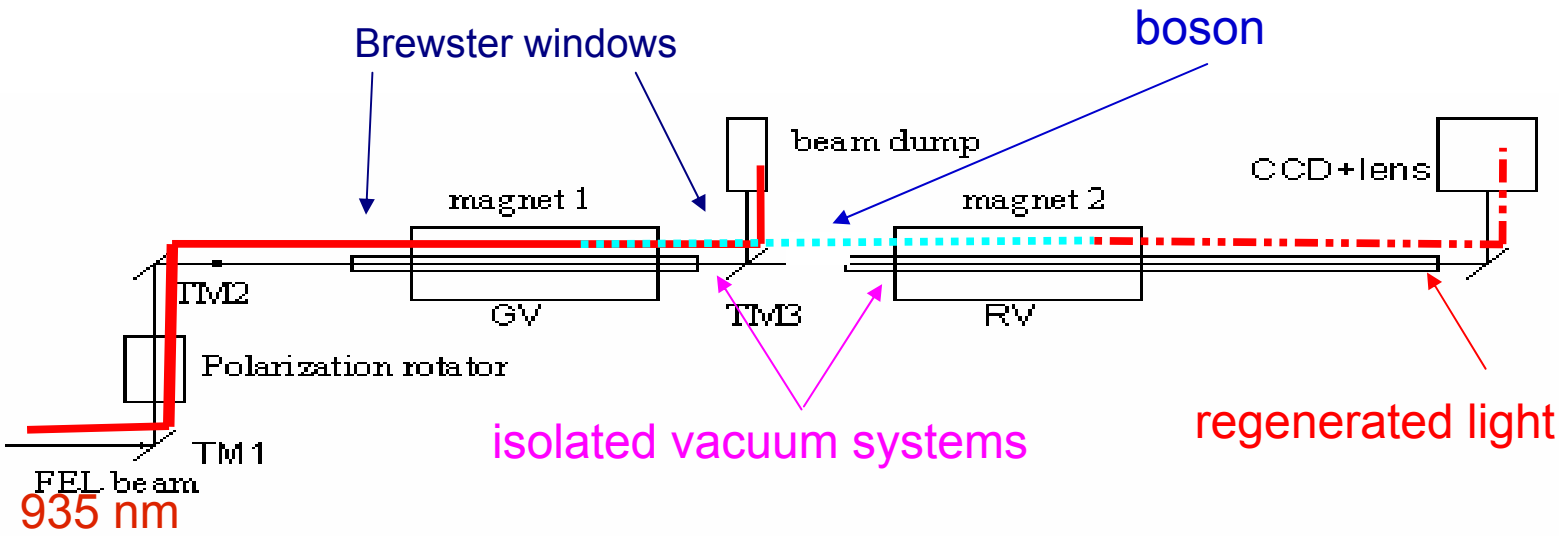


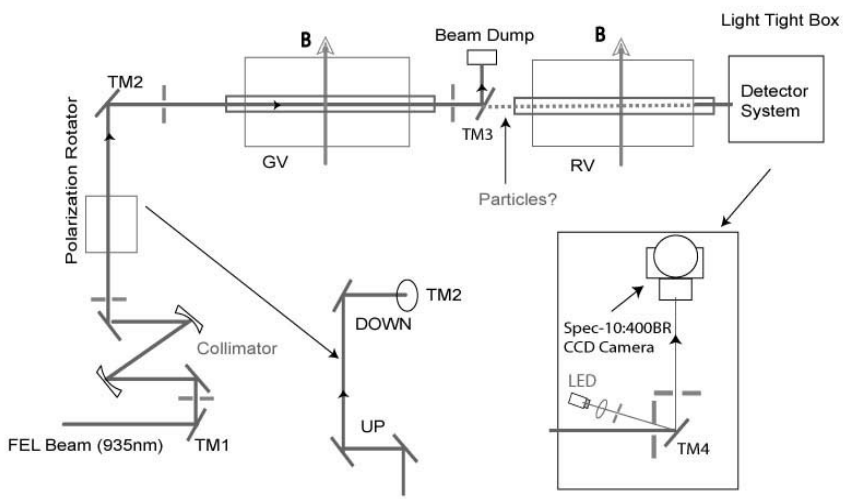
OTS upgrades

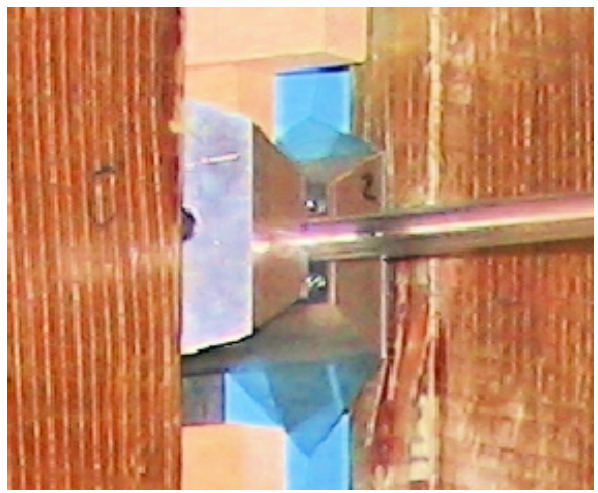
- since Spring ‘07, improvements were made to stabilize the FEL OTS, as well as the LIPSS OTS.
  - shielding of optical components against stray light was installed in both the FEL optical cavity and in the collimator.
  - new LIPSS OTS mirrors, designed for 930nm operation were installed.
  - a new automated stabilization system for the LIPSS OTS.

- improved analysis software.

LIPSS – experiment schematic.



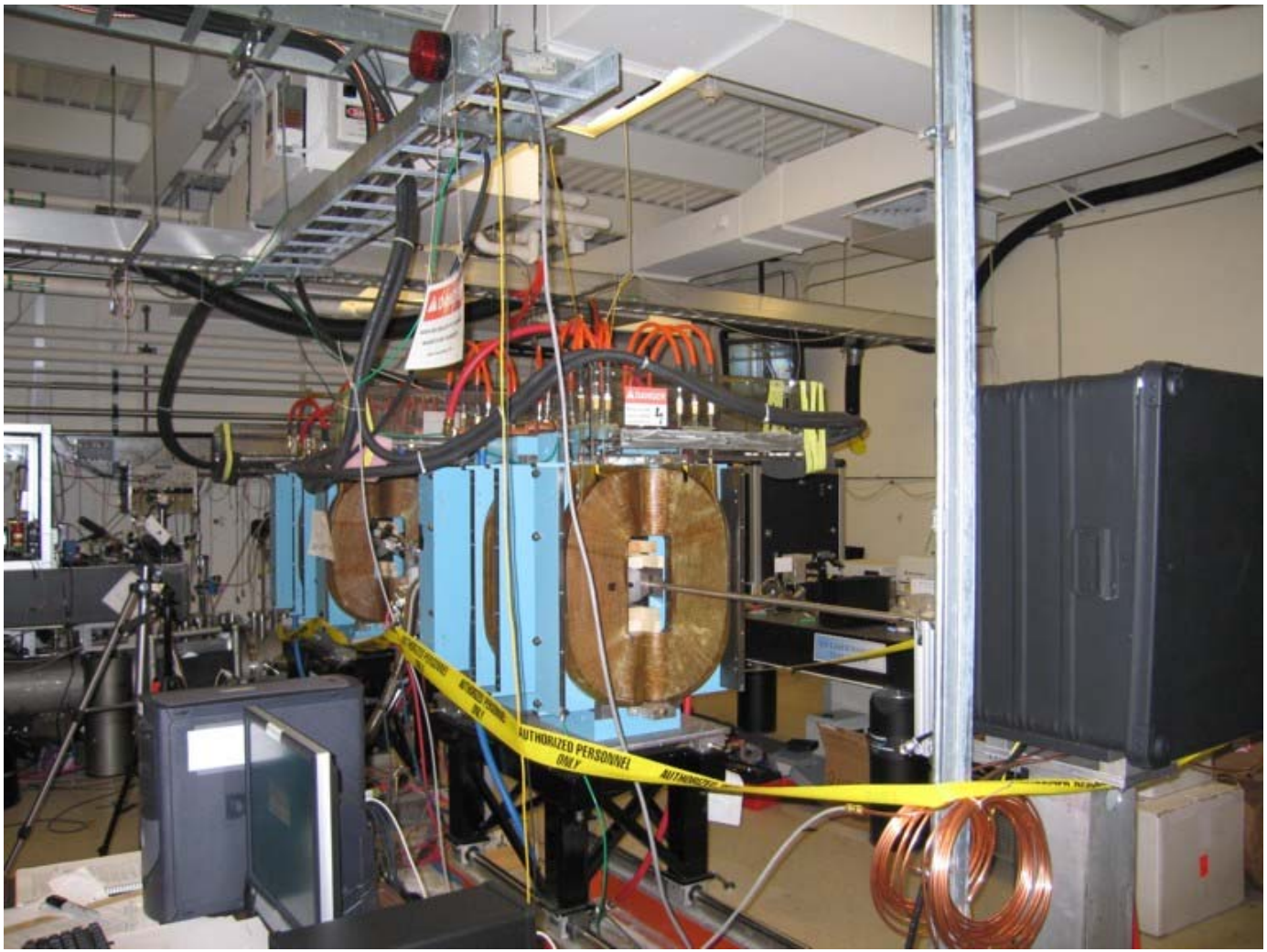




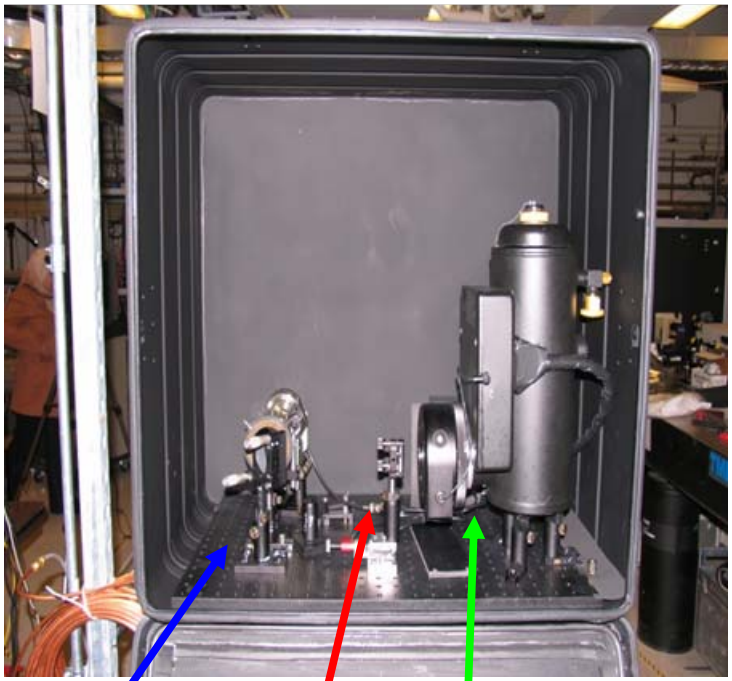
alignment procedure

- align with HeNe through the OTS and beam line to the CCD array
- align with HeNe from lab 1 to CCD array
- with FEL in alignment mode (<watt) align to CCD array
- same focus on CCD array in each case
- same position on TM's in each case
- button up LTB, increase FEL power

LIPSS experimental setup

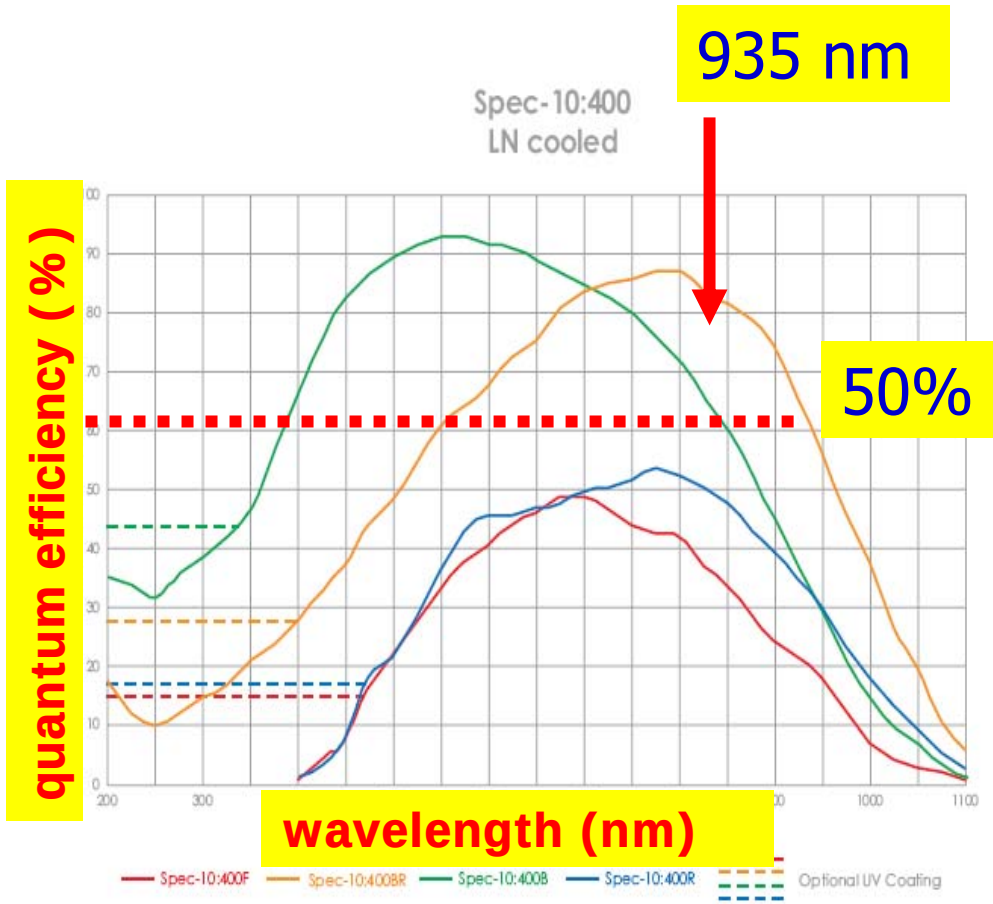


LIPSS detector chamber

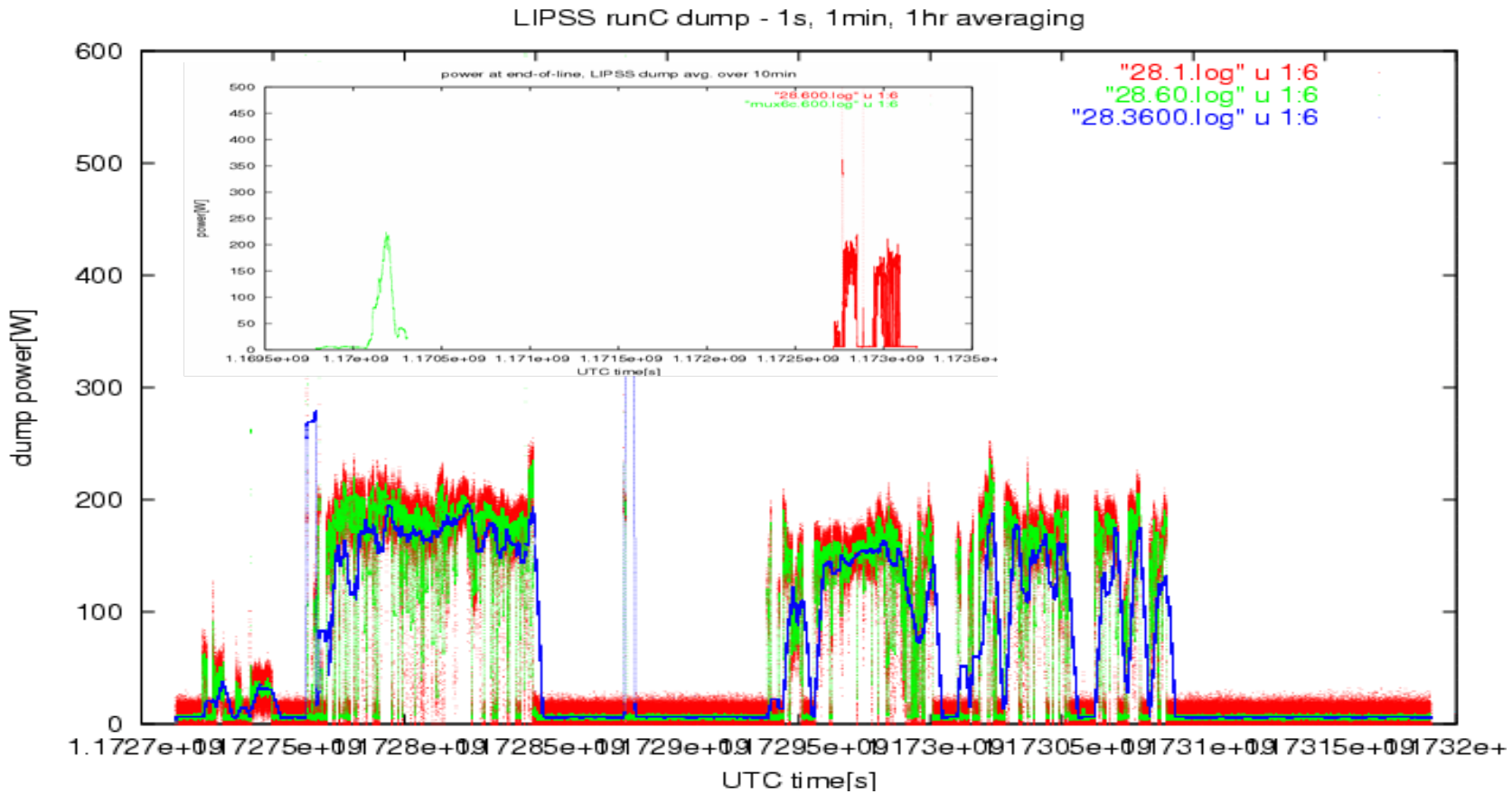


Spec10:400BR-LN camera

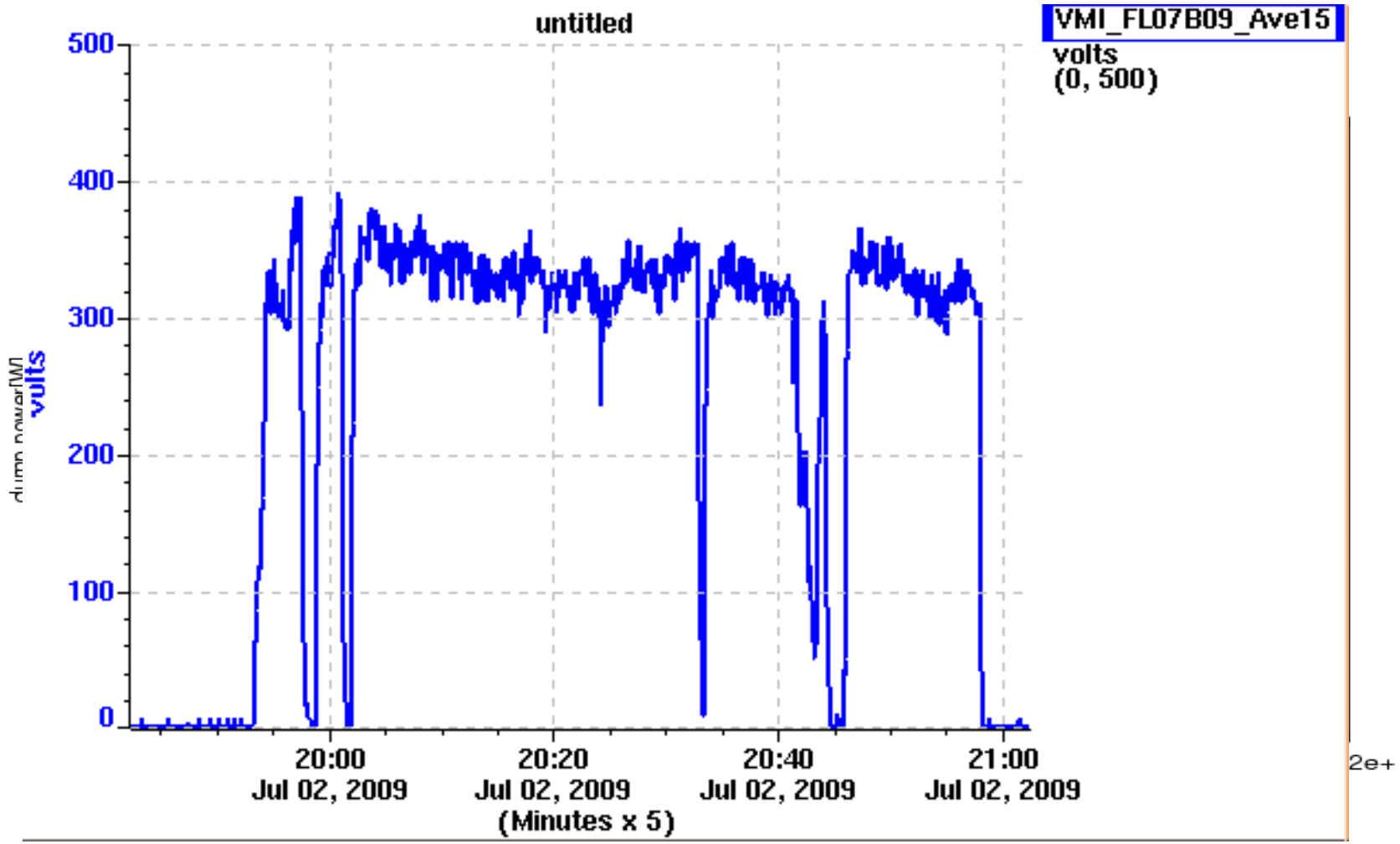
LN2 cooled:
<1 e/pix/hour dark noise !!!



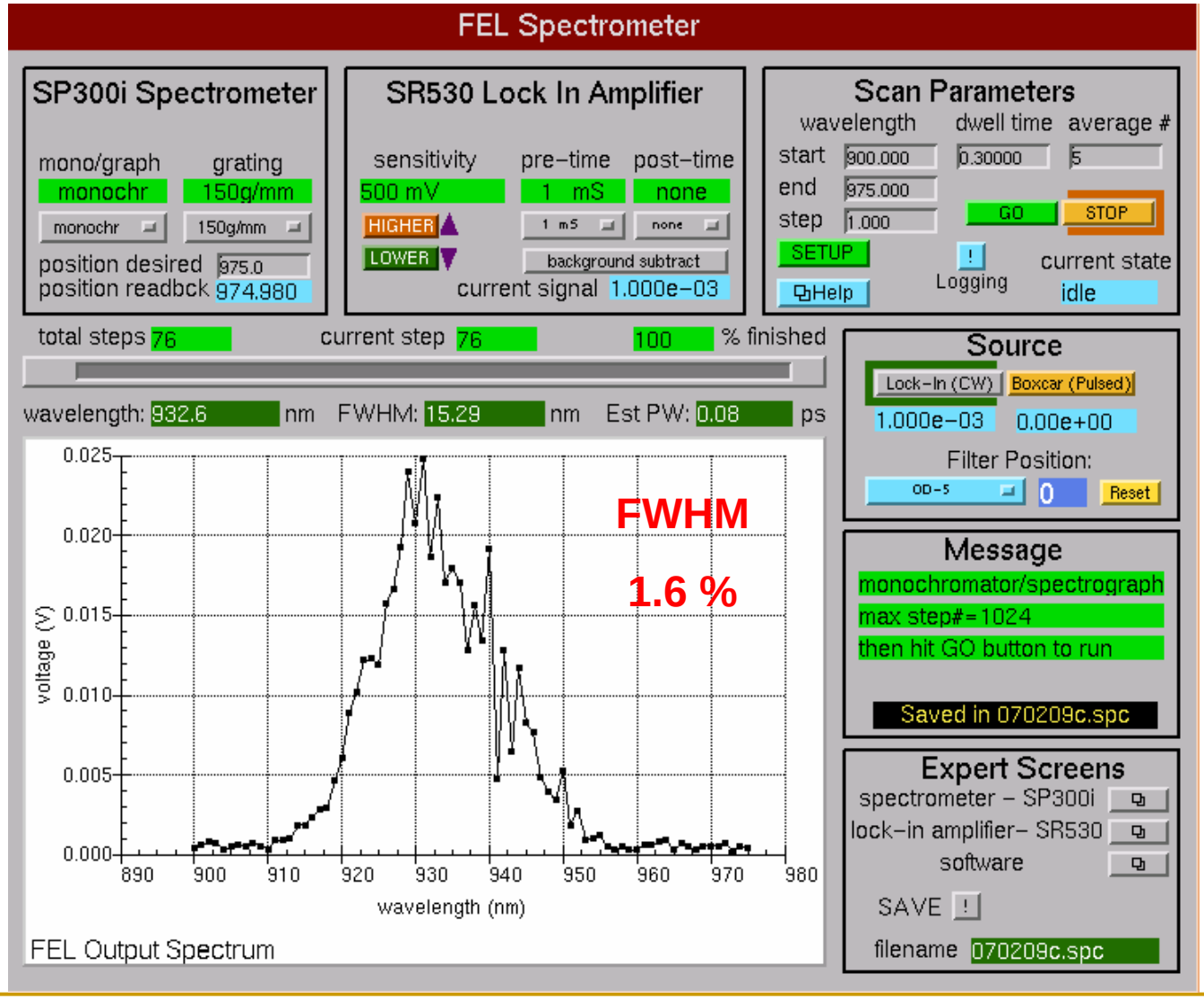
power delivered to the LIPSS beam dump in 2007



power delivered to the LIPSS beam dump in 2009



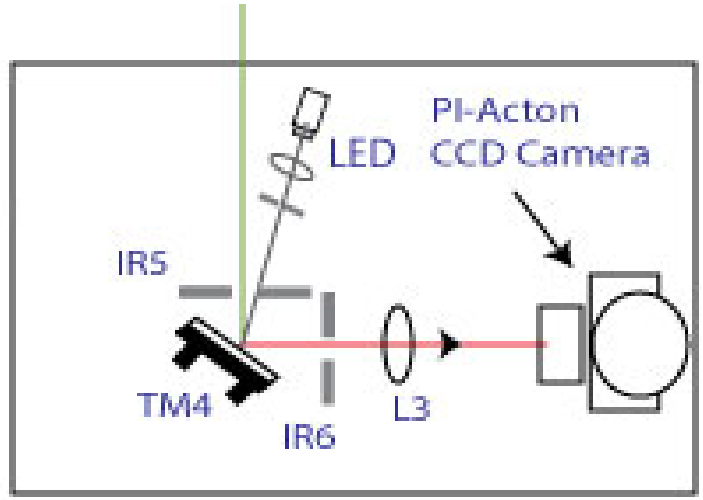
FEL tuned to 935 nm

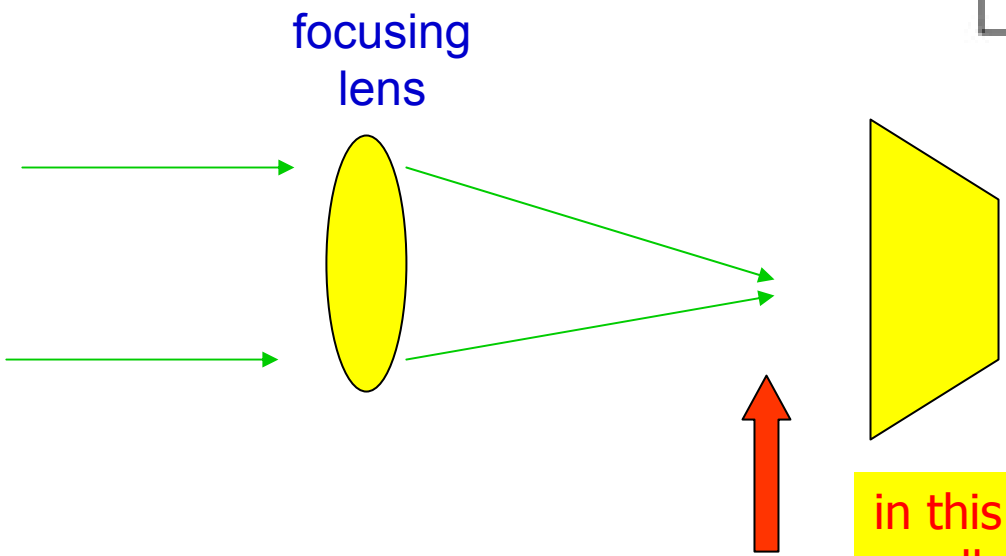


parameters for latest LIPSS run (2009)

B-field:	1.77 T
magnet length:	1.01 m
IR FEL power	>= 0.35 kW (avg)
IR FEL wavelength	935 nm (1.33 eV)
quantum efficiency	0.45
linear polarization	100%
acceptance	100%
experimental efficiency	~ 90%

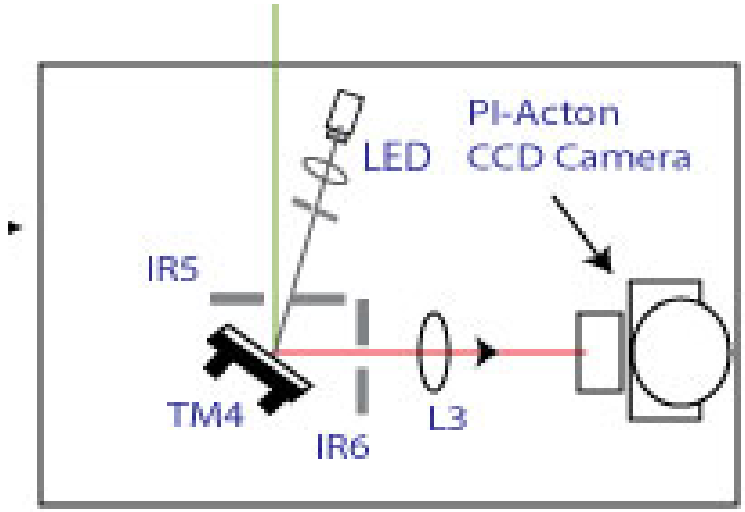
increase S/N: focusing light

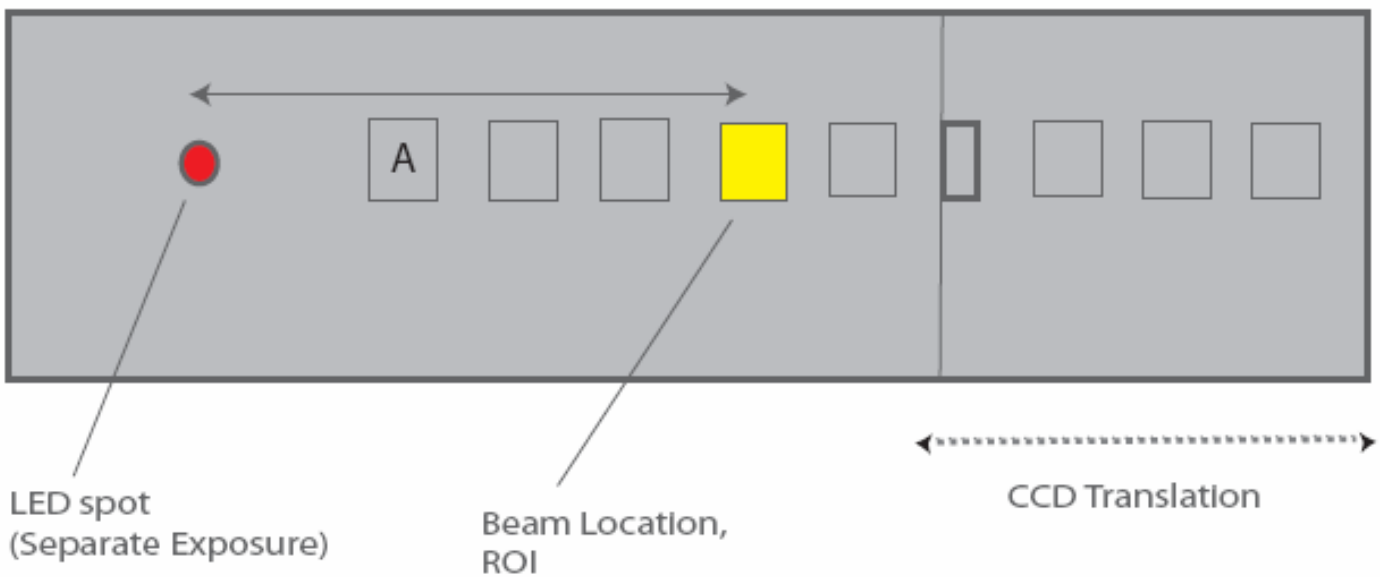




in this run the beam illuminated a 3x3 (or smaller) array of 20 micron x 20 micron pixels

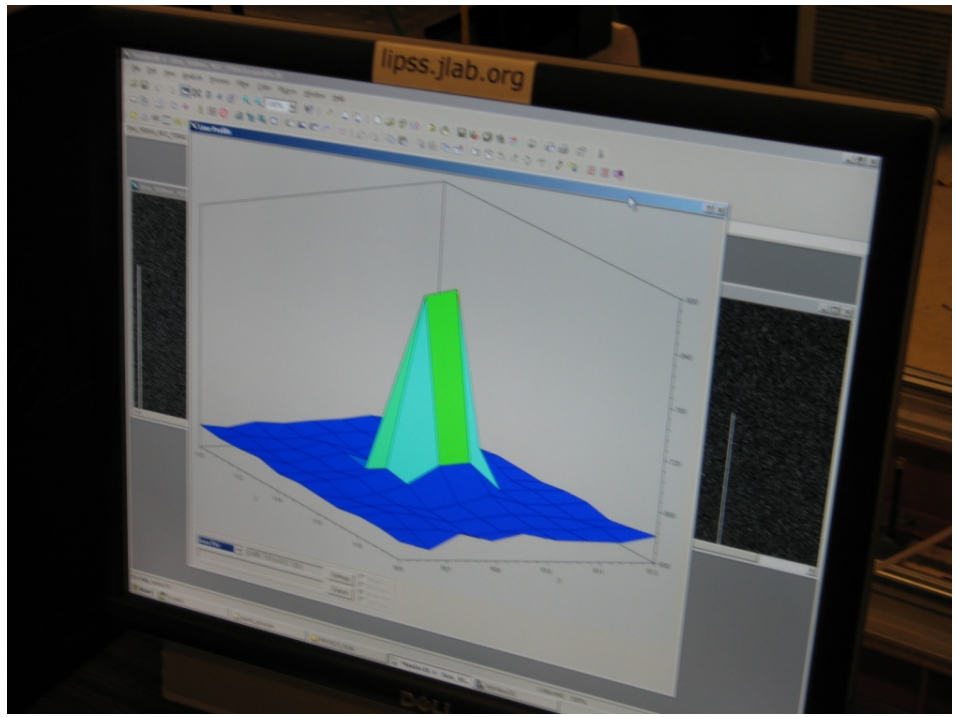
data taking . . .


PI-Acton
CCD Camera
LED
IR5
TM4
IR6
L3


A
LED spot
(Separate Exposure)
Beam Location,
ROI
CCD Translation

procedure . . .

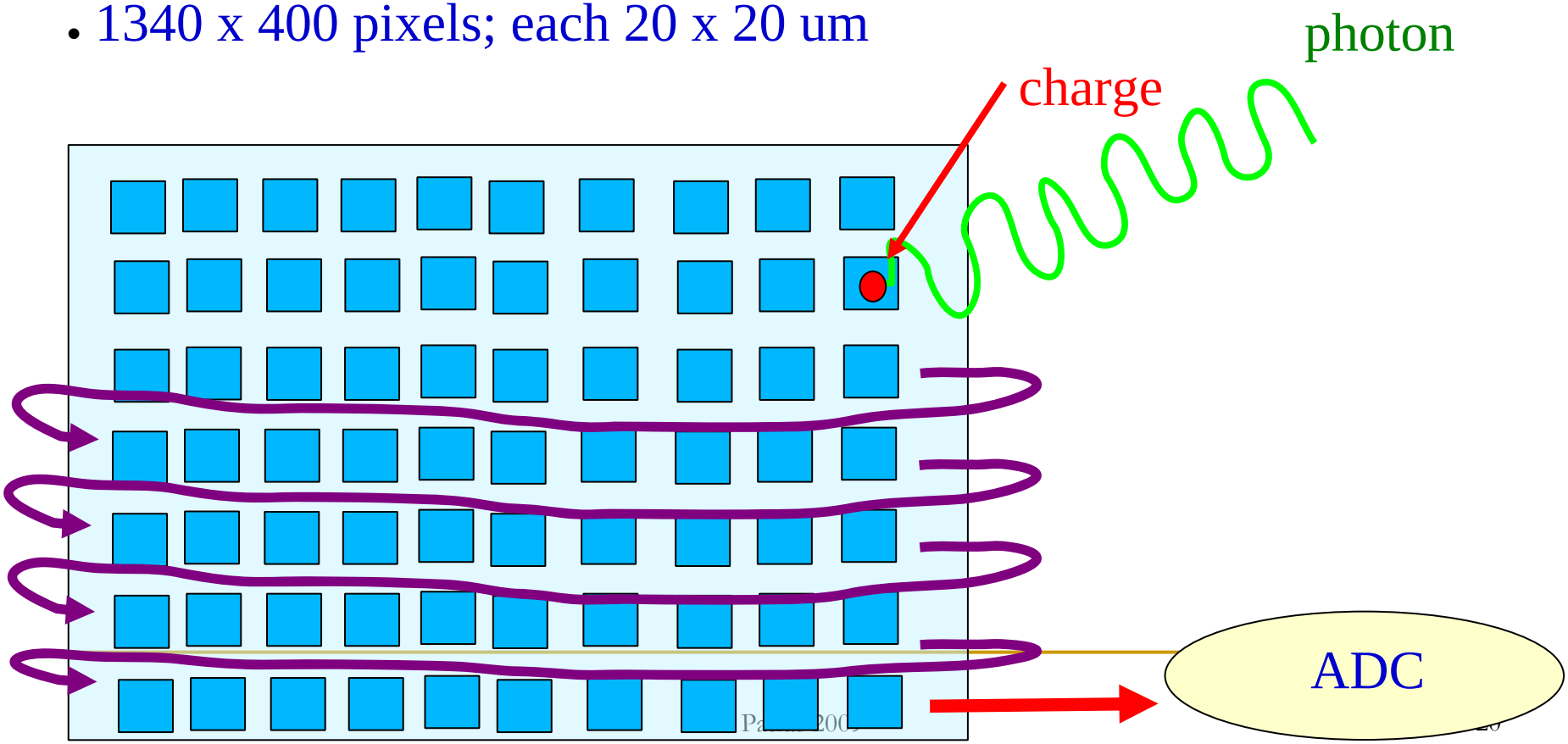
- take short run at beginning
- take led run
- take data run
- translate detector
- repeat



led spectrum

Piacton 400BR-LN CCD camera

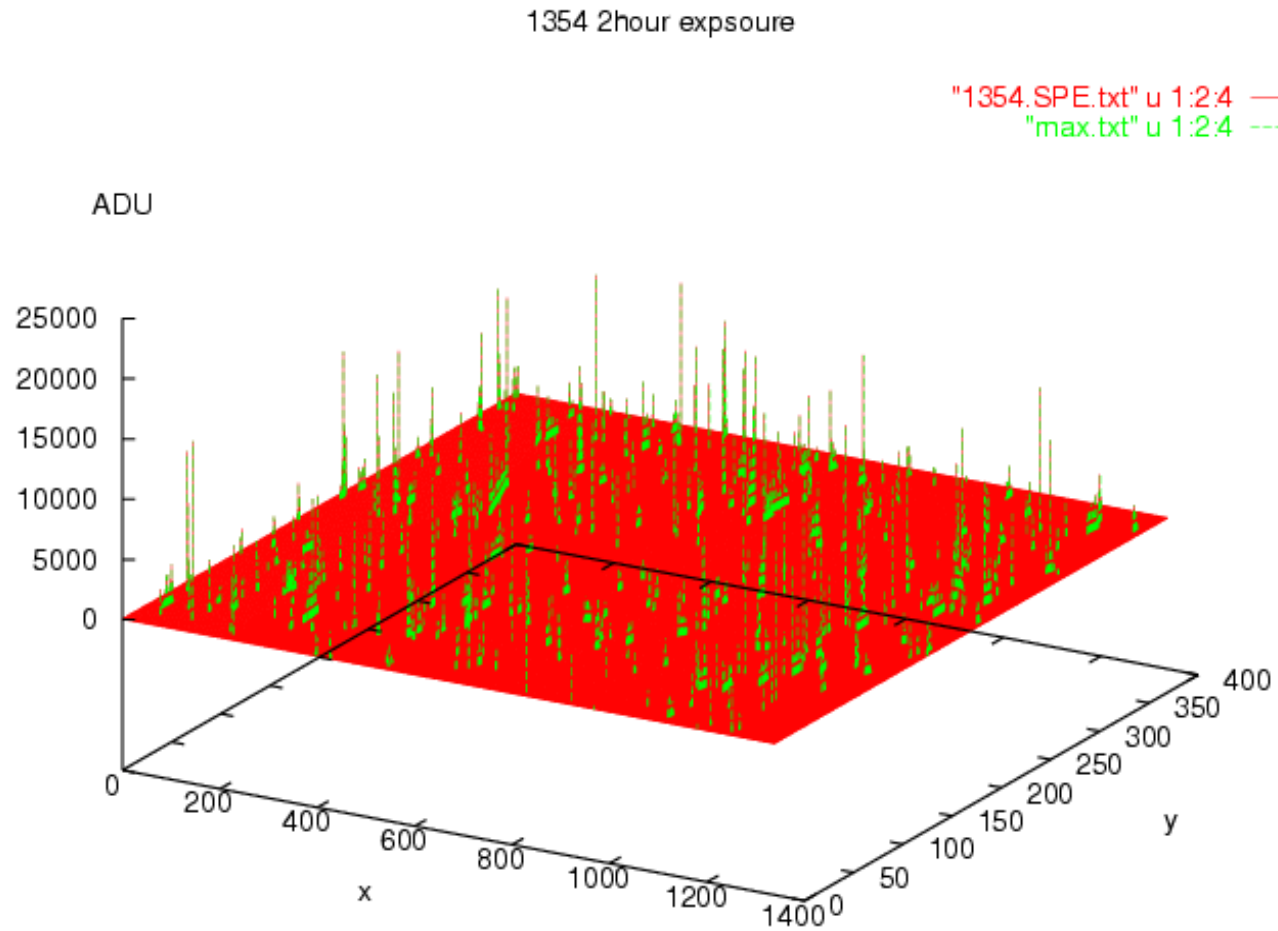
- good position resolution; no time resolution
- low dark current (cooled with LN_2)
- cosmic rays and background radiation induced events identified
- charge in each pixel converted to an ADU count
- 1340 x 400 pixels; each 20 x 20 um



backgrounds

- **thermal noise**
  - **< 1 count/hour/pixel at -120^{o}C**
- **read noise**
  - **2.5 counts per read (every 1 hour in 2009)**
- **stray light**
  - **< 1 count/hour/pixel**
- **cosmic rays in vacuuum pipe gas**
  - **negligible (~10^{-6} Torr vacuum)**
- **cosmic rays striking CCD array**
  - **easy to identify and discard**
- **radiation from FEL**
  - **negligible**
- **. . .**

two hour run characterize background



cosmic rays

thermal noise

stray light

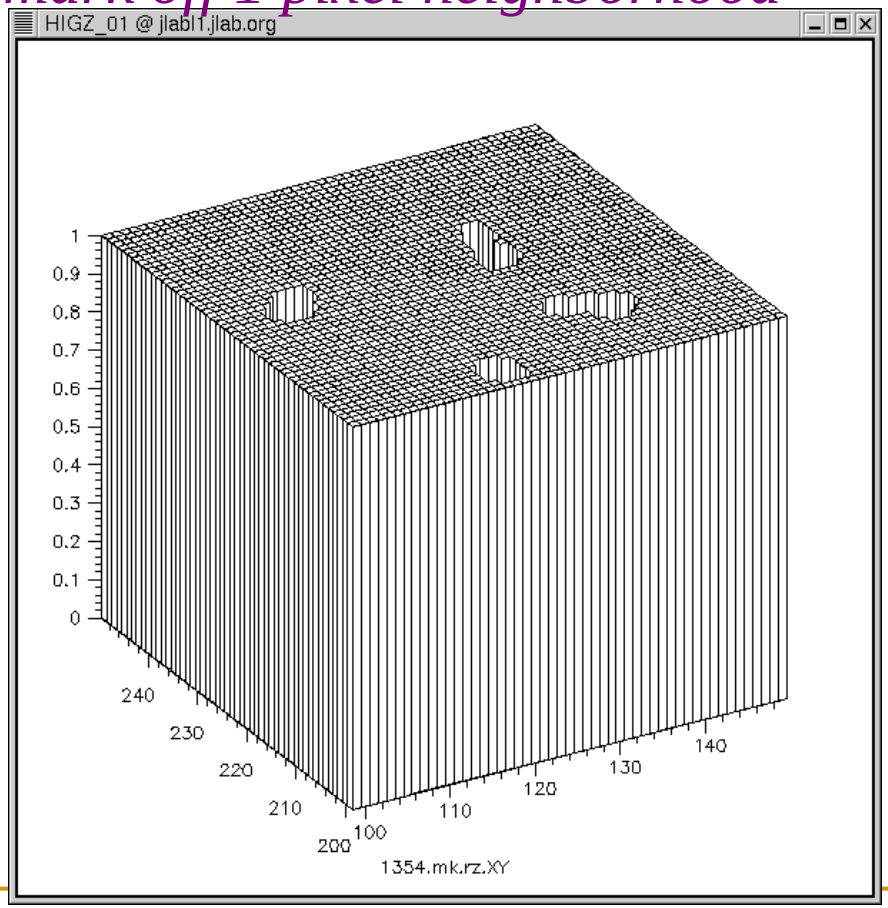
read noise

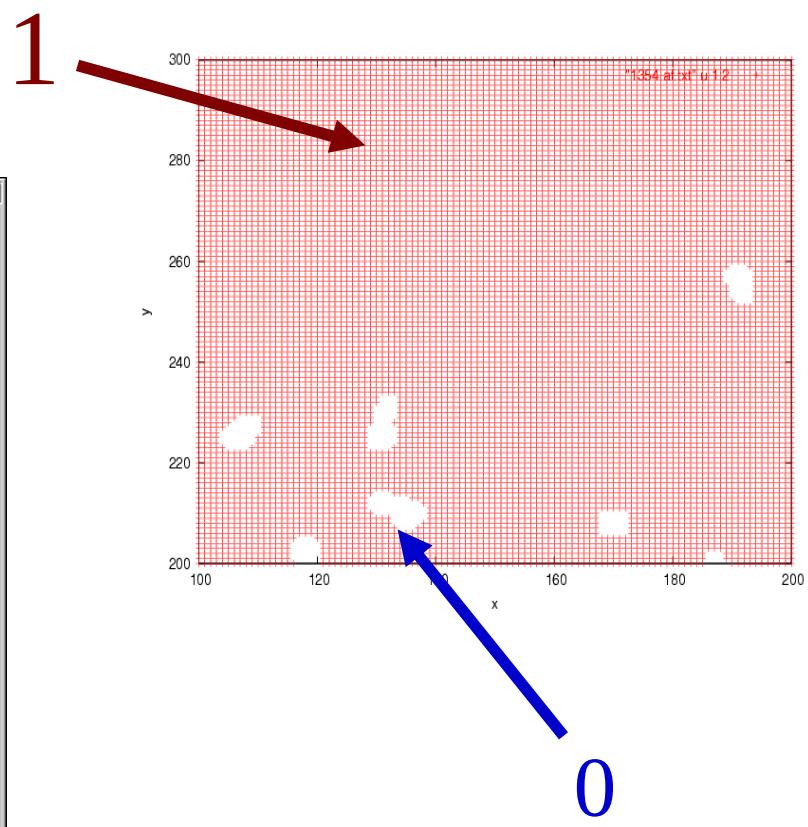
all minimized

to remove “anomalies”, a logical mask is created...

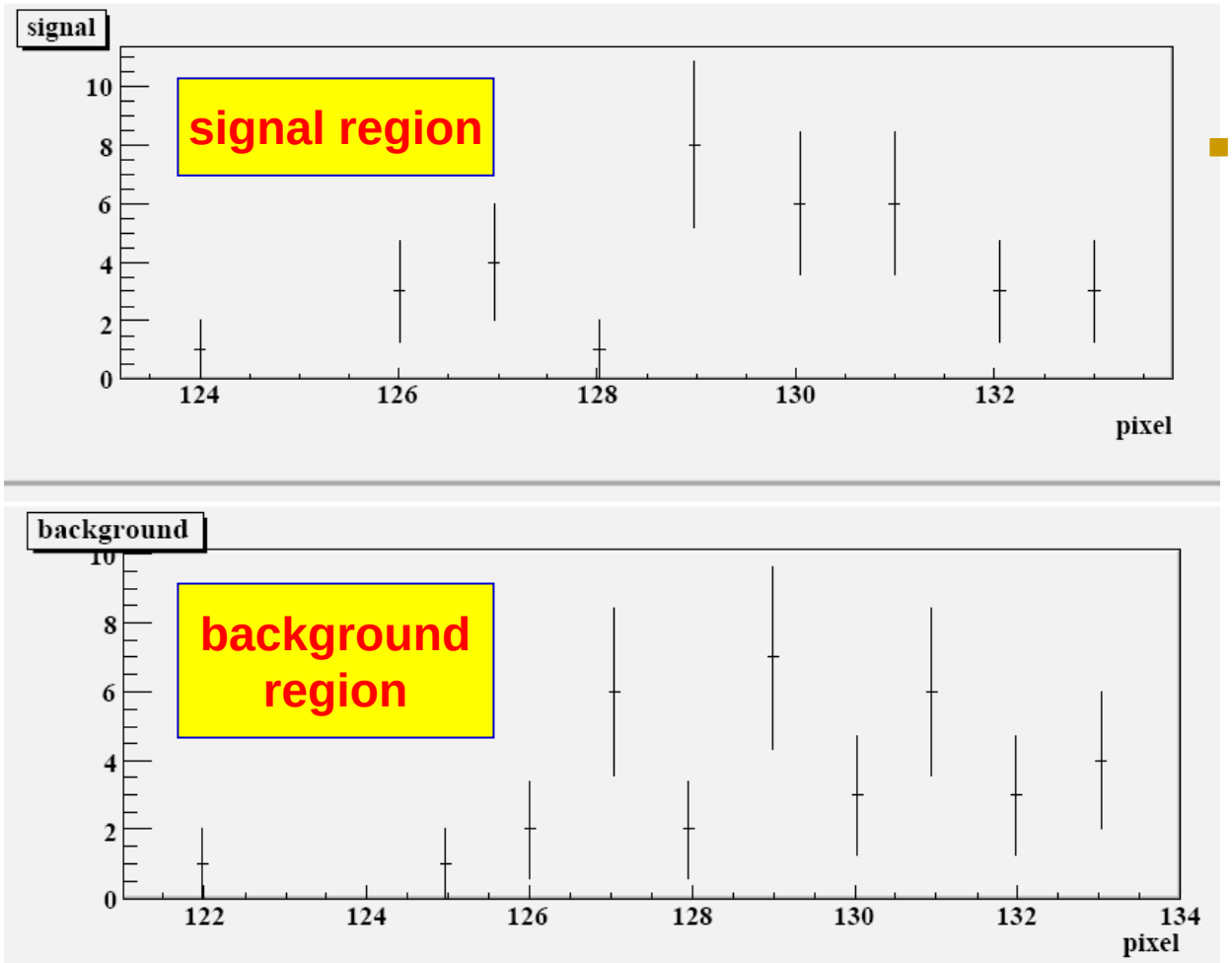
estimate σ based on 5-95% cut;
then cut on 10 x σ

also mark off 1 pixel neighborhood





data analysis . . .

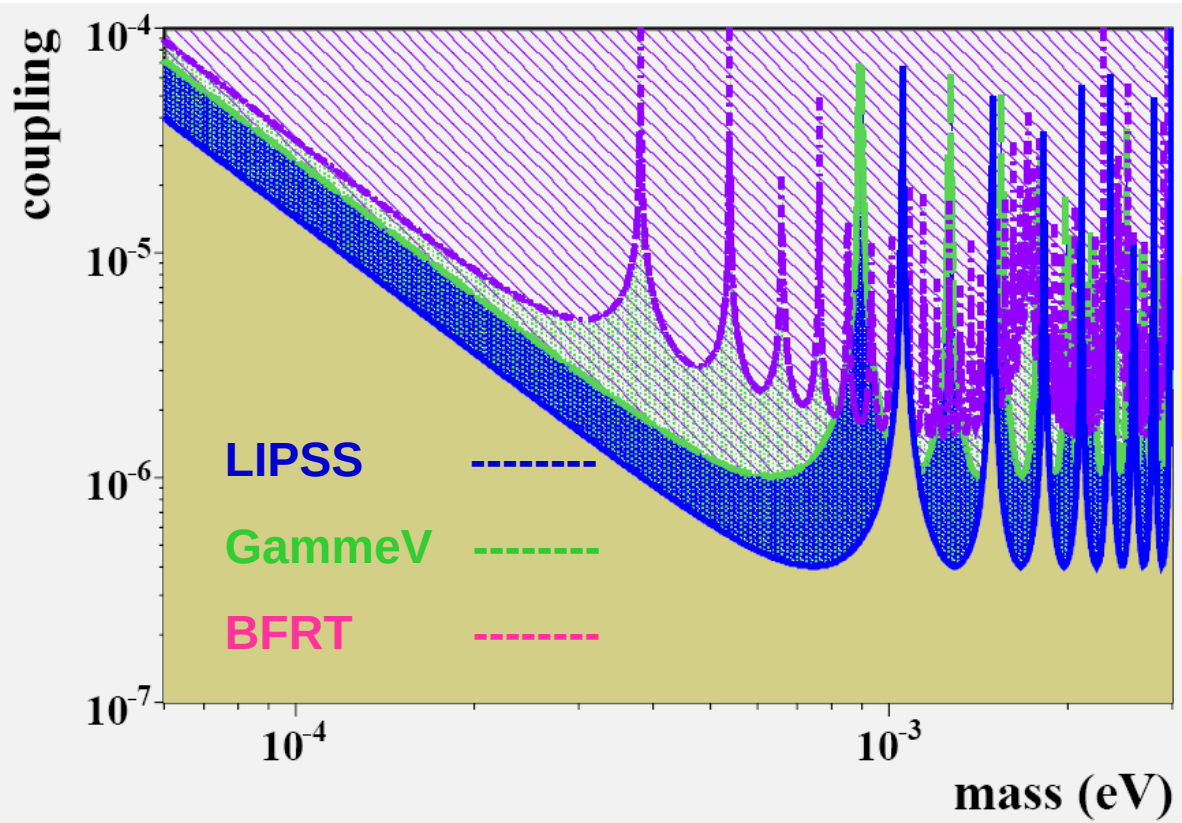


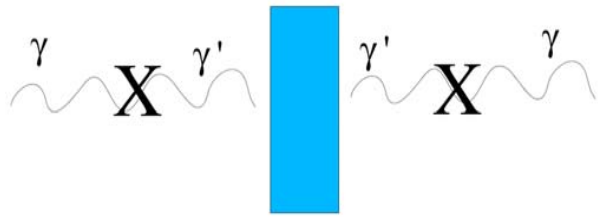
- two ways to determine background
  - All CCD pixels not in the signal region
  - CCD pixels in signal region with no FEL light
    - shutter closed/shutter open
    - electron beam on versus off
    - lights on versus lights off
    - temp dependence

extra U(1) gauge boson (paraphoton)

LIPSS results

arXiv:0810.4189 (submitted to PLB)





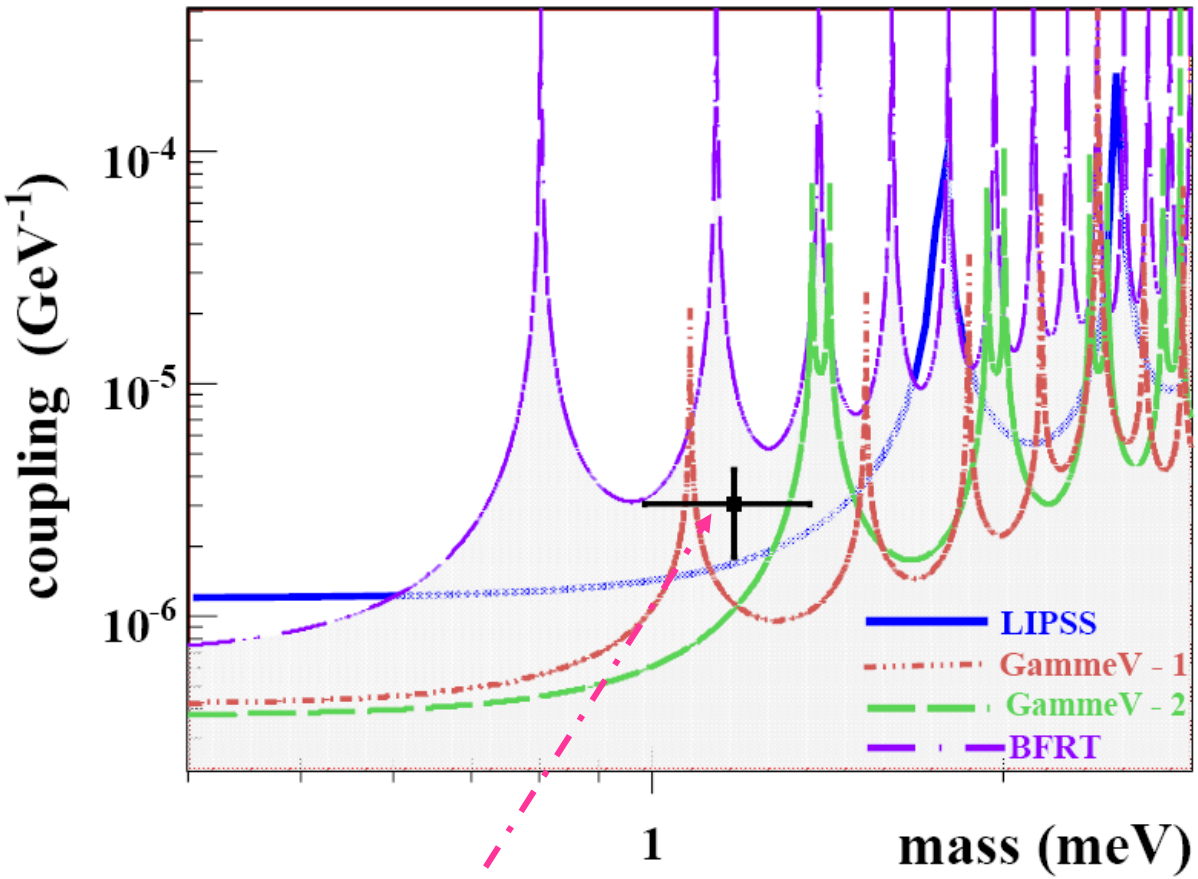
$$P = 16\chi^4 \left[\sin\left(\frac{\Delta k L_1}{2}\right) \sin\left(\frac{\Delta k L_2}{2}\right) \right]^2$$

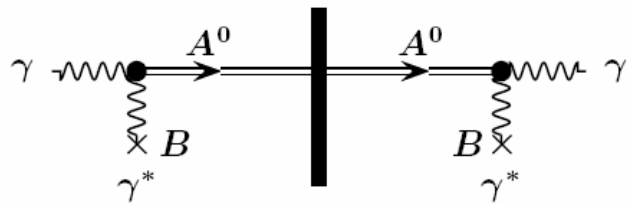
χ coupling,

Δk momentum transfer,

L propagation length

axion-like particle search





$$P_{\gamma\to\varphi} = \frac{1}{4}(gBL)^2 \left\{ \frac{\sin\left(\frac{m_\varphi{}^2 L}{4\omega}\right)}{\frac{m_\varphi{}^2 L}{4\omega}} \right\}^2$$

LIPSS

PRL (2008)
arXiv:0806.2631

*** PVLAS; now disclaimed**

LIPSS status

- just completed a new experimental run at Jefferson Lab during week June 29-July 2, 2009.
- laser light polarized parallel to magnetic field
- average ~350 watts; 935 nm
- data under analysis presently

most recent run – students and teachers

- Joe Amma – Middle School teacher, Newport News, VA
- Jennifer Caldwell – Univ of Ark, Pine Bluff
- Jonathan Evans – South Carolina State Univ
- Taylor Robinson – Heritage High School, Hampton, VA

LIPSS collaboration

A. Afanasev, R. Ramdon

Hampton University

K. Beard[#], G. Biallas, J. Boyce, M. Shinn

Jefferson Lab

O.K. Baker, M. Minarni [!], P. Slocum, A. Martin

Yale University

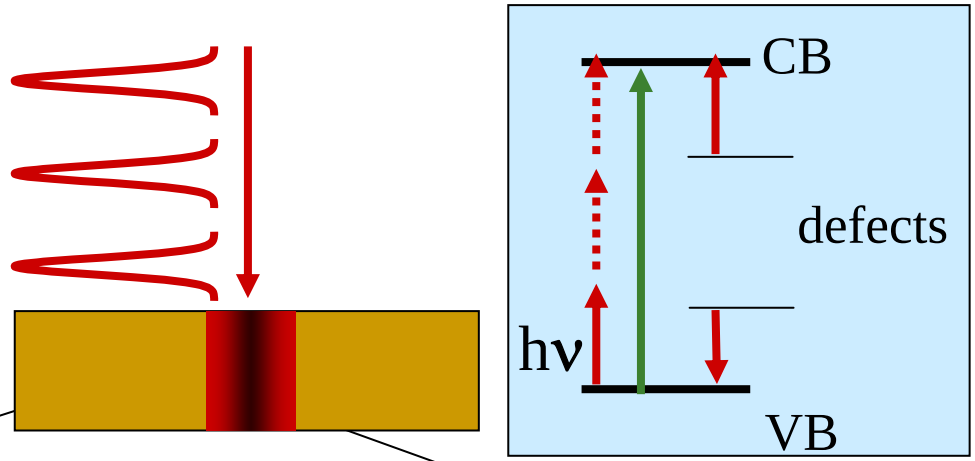
[!]*now at Riau Univ, Indonesia* [#]*now at Muons Inc, Batavia*

funded mainly by the Office of Naval Research

Backup slides

Native and laser induced defects impact a coatings' resistance to laser induced absorption

(courtesy W. Rudolph UNM)



absorption by defects
- vacancies
- band tail states
- impurities
- self-trapped excitons, polarons, -and color centers

(material intrinsic, from coating procedure, light induced)

heat release lattice instabilities

band-to-band absorption
- multiphoton absorption
- single photon absorption of higher harmonics

performance deterioration damage

laser-induced defects (self-trapped excitons, polarons, & color centers

PAST RESEARCH SUPPORTS THE EFFECT OF HARMONICS

- V. Sanders, J. Early, and W. Leamon, "The response of Multilayer Dielectric Coatings to Low Fluence Ultraviolet Light Exposure" Proc. SPIE 1438, 561 (1989)
- Our IBS coatings have ~ 0.3 wt.% ZrO_2 in the HfO_2.

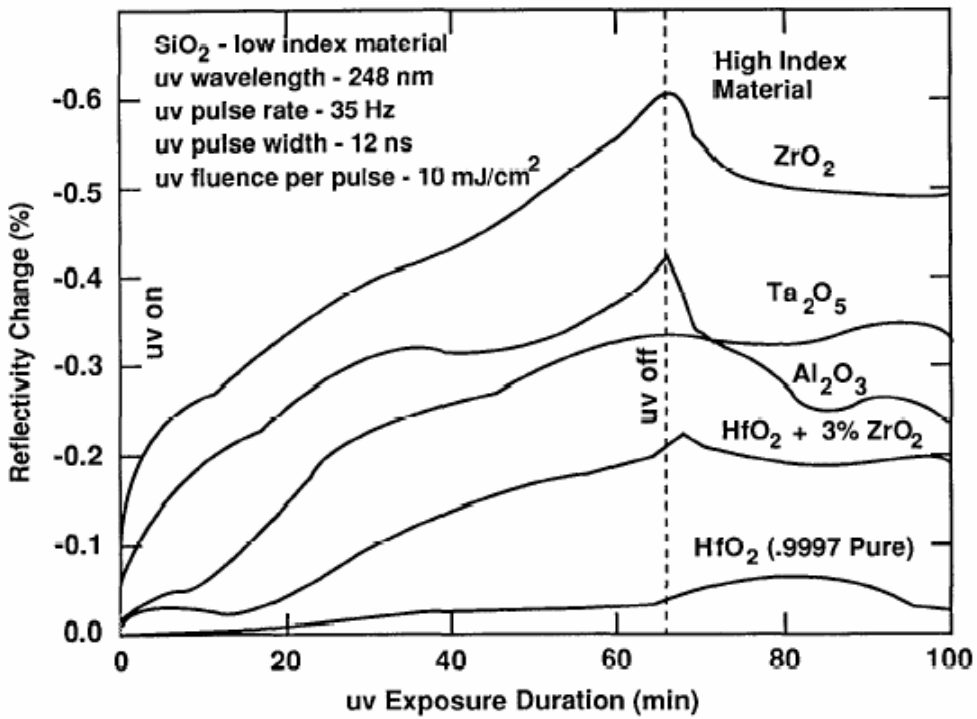
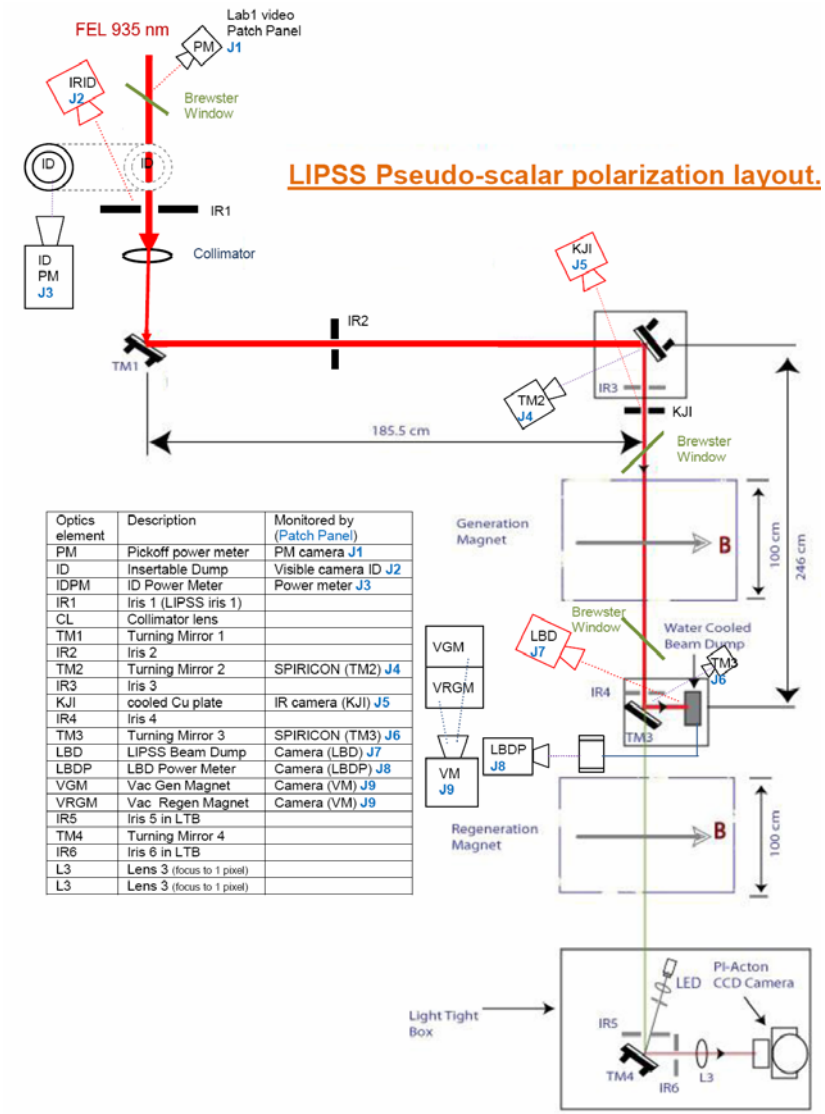


Figure 3. Comparison of high index materials in uv-damage experiment



Optics element	Description	Monitored by (Patch Panel)
PM	Pickoff power meter	PM camera J1
ID	Insertable Dump	Visible camera ID J2
IDPM	ID Power Meter	Power meter J3
IR1	Iris 1 (LIPSS iris 1)	
CL	Collimator lens	
TM1	Turning Mirror 1	
IR2	Iris 2	
TM2	Turning Mirror 2	SPIRICON (TM2) J4
IR3	Iris 3	
KJI	cooled Cu plate	IR camera (KJI) J5
IR4	Iris 4	
TM3	Turning Mirror 3	SPIRICON (TM3) J6
LBD	LIPSS Beam Dump	Camera (LBD) J7
LBDP	LBD Power Meter	Camera (LBDP) J8
VGM	Vac Gen Magnet	Camera (VM) J9
VRGM	Vac Regen Magnet	Camera (VM) J9
IR5	Iris 5 in LTB	
TM4	Turning Mirror 4	
IR6	Iris 6 in LTB	
L3	Lens 3 (focus to 1 pixel)	
L3	Lens 3 (focus to 1 pixel)	

threshold effect (Adler et al, hep/ph 0801.4739v4)