Synchrotron radiation applications with UV radiation

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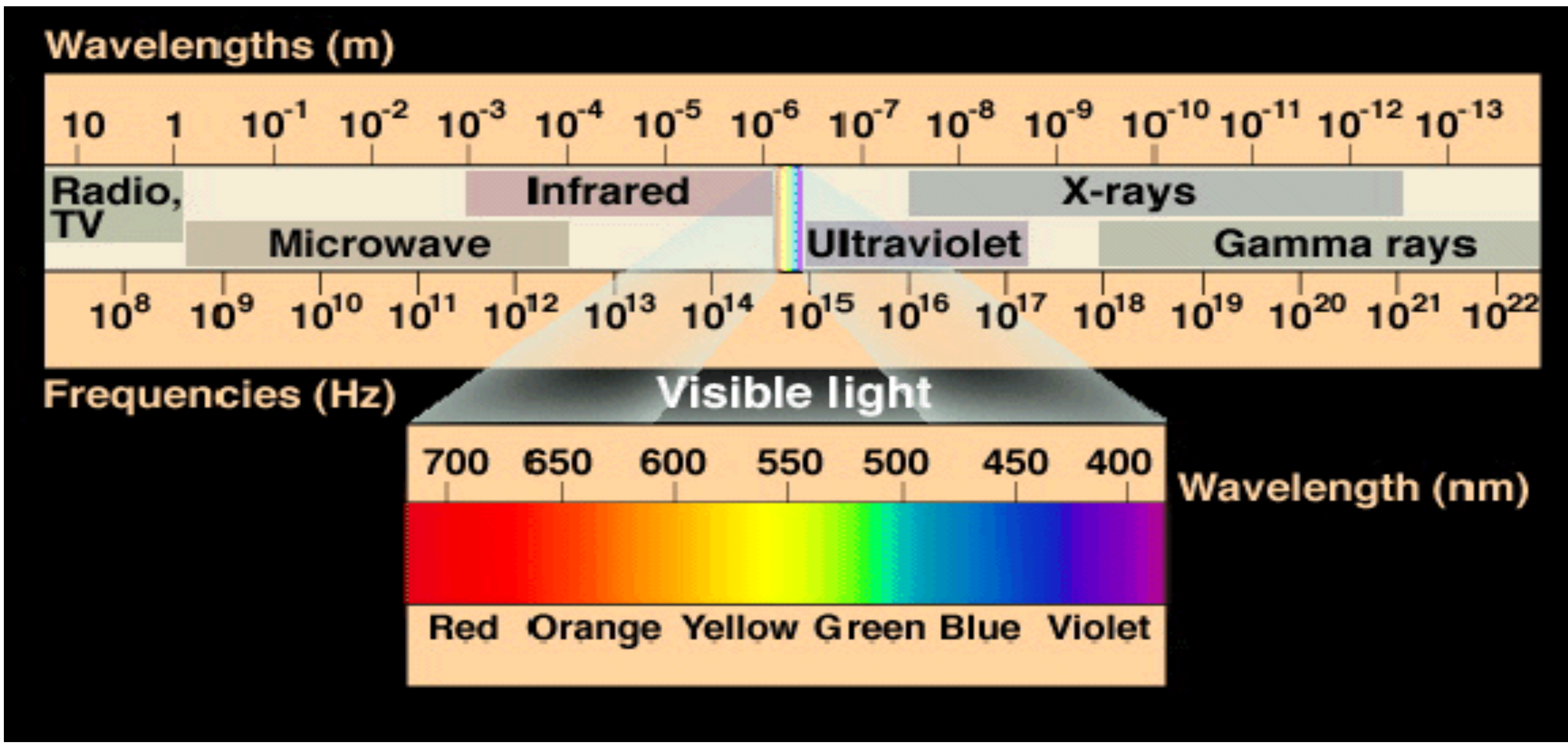
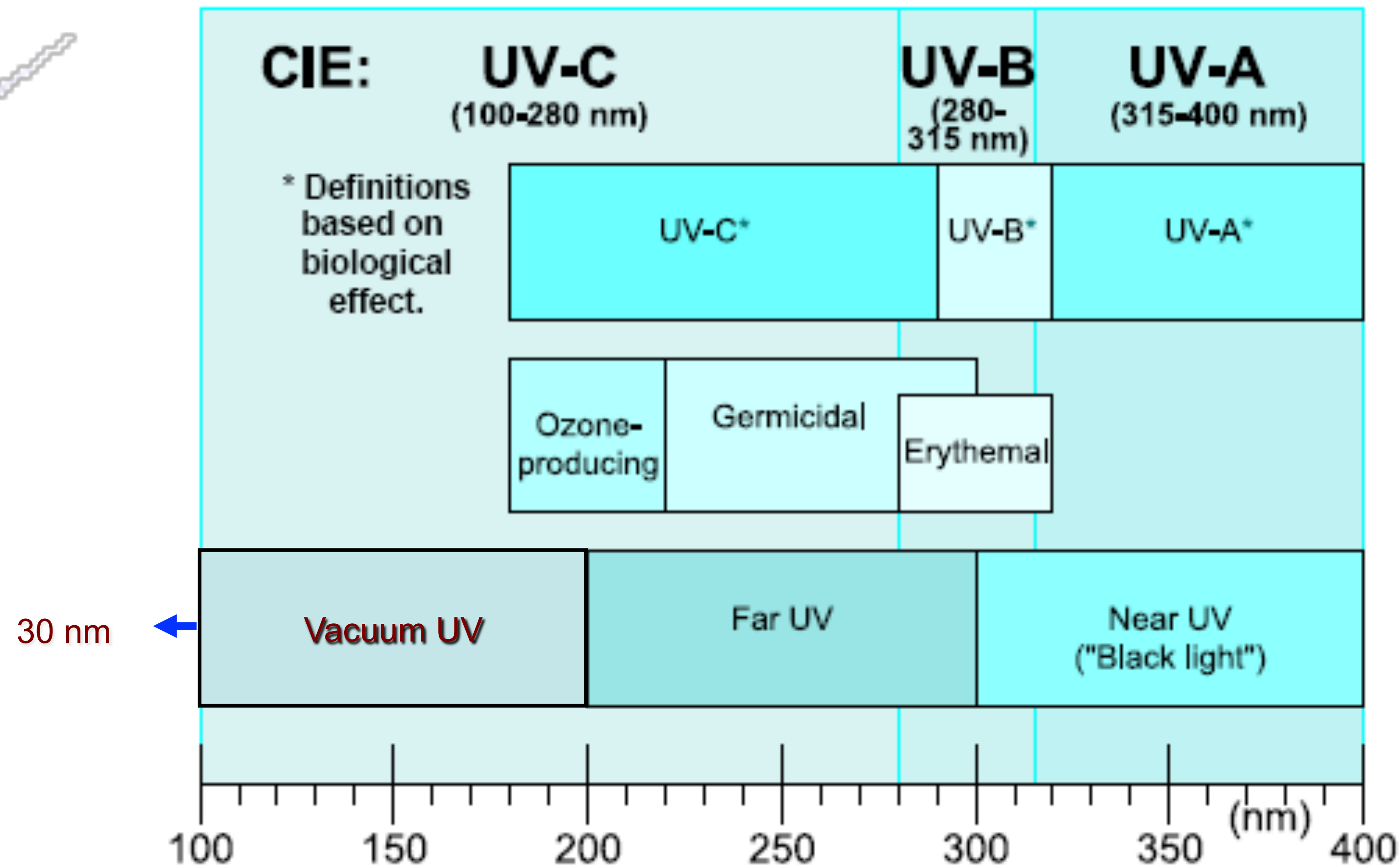
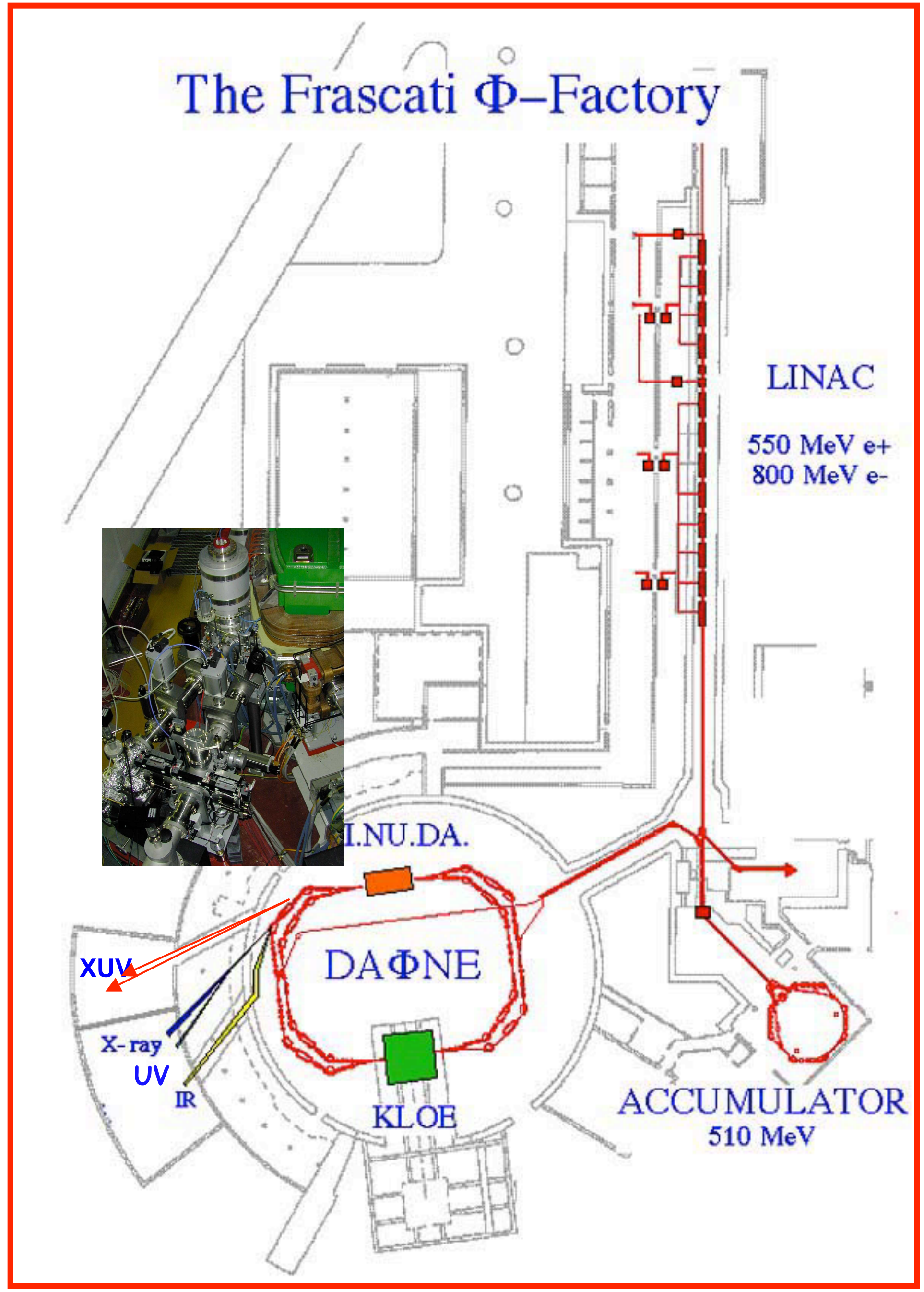
Radiazione e.m.
Spettro



Radiazione e.m.
Spettro UV




The Frascati Φ–Factory
LINAC
550 MeV e+
800 MeV e-
I.NU.DA.
DAΦNE
XUV
X-ray
UV
IR
KLOE
ACCUMULATOR
510 MeV

DXR-2/SOURCE: UV-VIS branchline @ LNF

- Test Facility to exploit the synchrotron radiation at DAFNE-L for electro-optical testing, calibration and characterization of optical system and detectors in the VIS-UV domain (2 eV to 10 eV).

- Important features are

  ☺ Photon flux known and reproducible

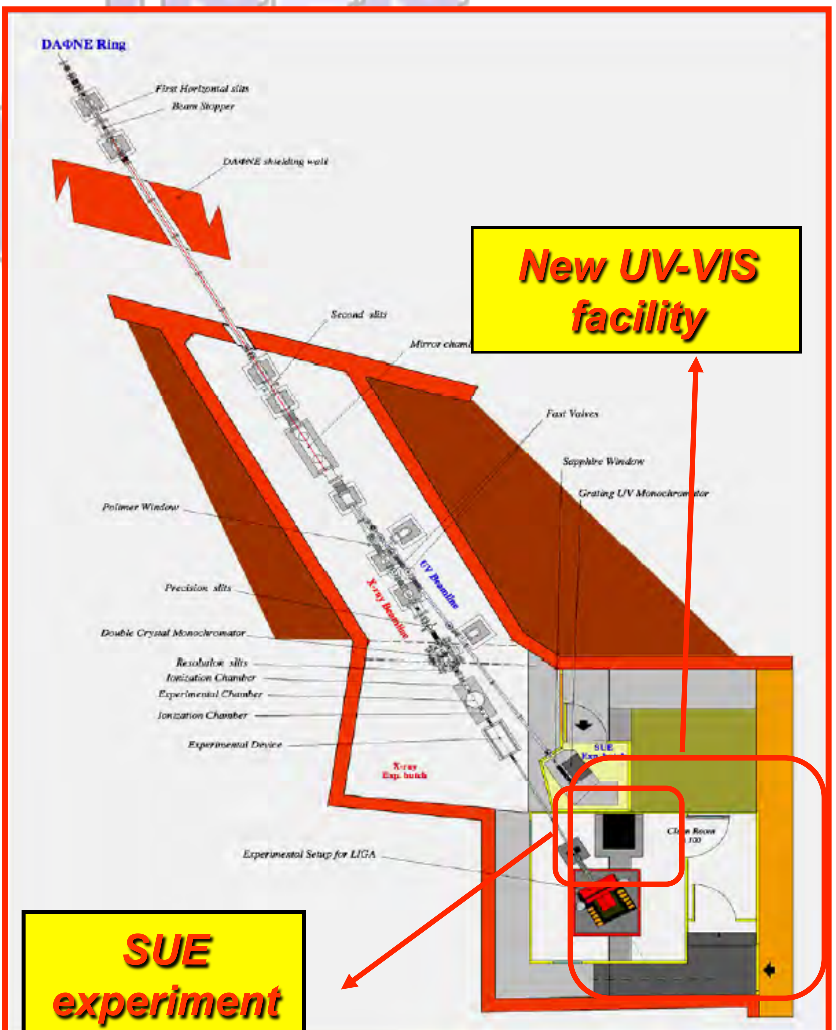
  ☺ Photon flux independent from the energy

  ☺ Ultra-fast and high frequency pulses (0.3 ns, 1GHz)

  ☺ Continuous spectrum radiation covering a wide domain

  ☺ Large spot size (~ mm)

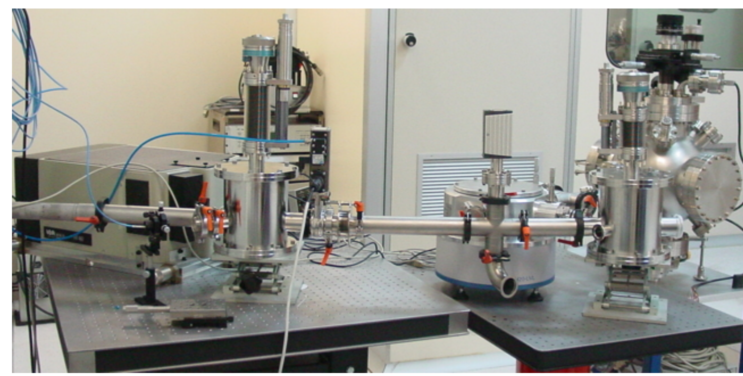
DAΦNE-L UV branch line



Wiggler UV branch line-deflection by a grazing incidence gold coated mirror (about 2°)

UV-VIS beamline new setup *2 -10 eV* (120-650 nm)

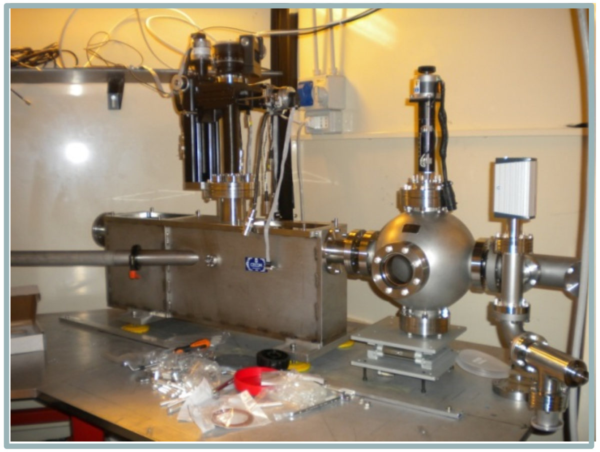
Branch line in a 1000-class *cleanroom*



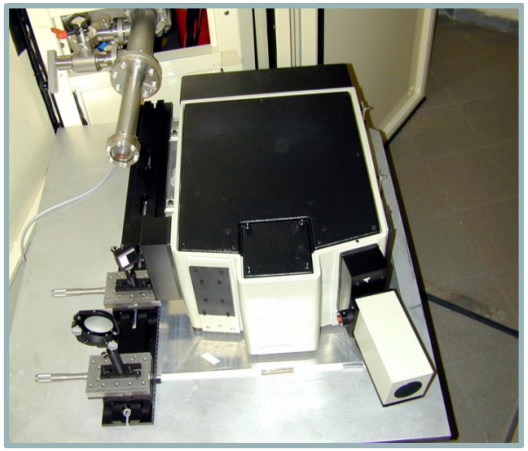
- Space applications
- Astrobiology and photo-biology
- Optical technology
- Detector technology
- Instrumentation testing and calibration
- Optical properties of materials

DAΦNE-L UV branch line

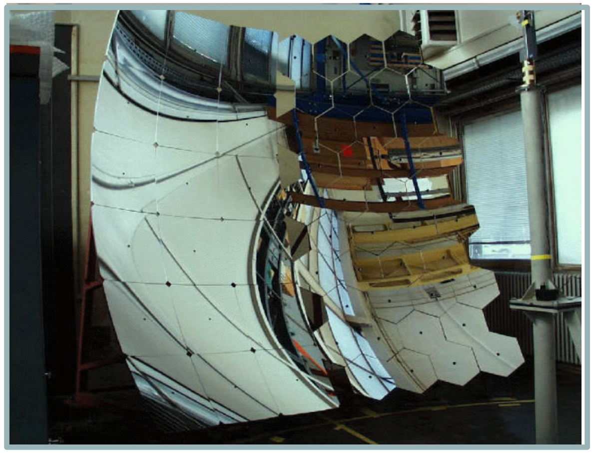
UV-VIS monochromatic radiation source (180-650 nm)



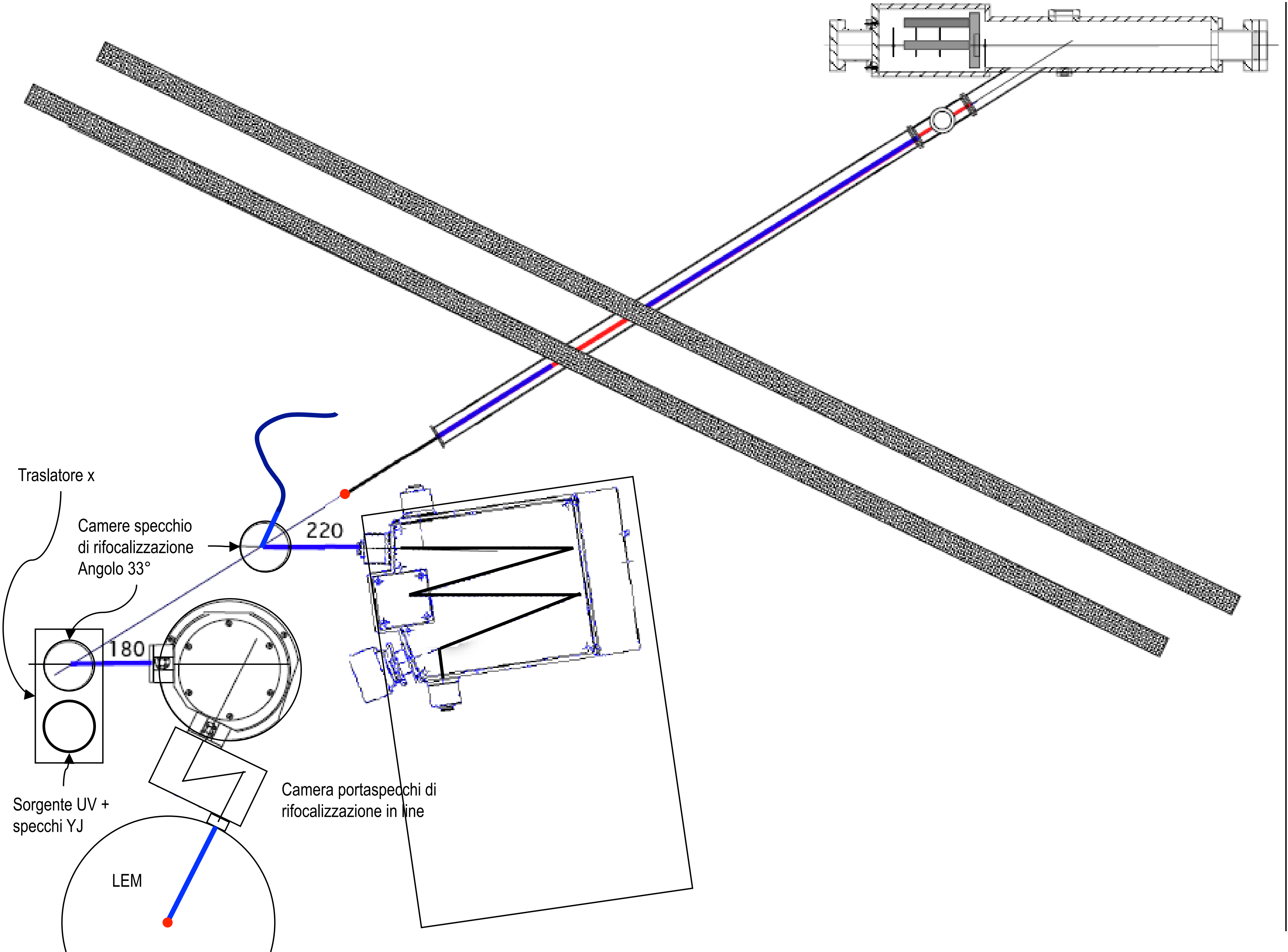
VUV monochromatic radiation source (120-250 nm)



UV-VIS radiation source (200-650 nm)



- Large optical systems (up to 4 mt) surface characterization
- UV photoageing of optical components and materials
- Detector calibration
- Photobiology and exobiology experiments



Traslatore x
Camere specchio
di rifocalizzazione
Angolo 33°
220
180
Sorgente UV +
specchi YJ
Camera portaspecchi di
rifocalizzazione in line
LEM

Spectral emission

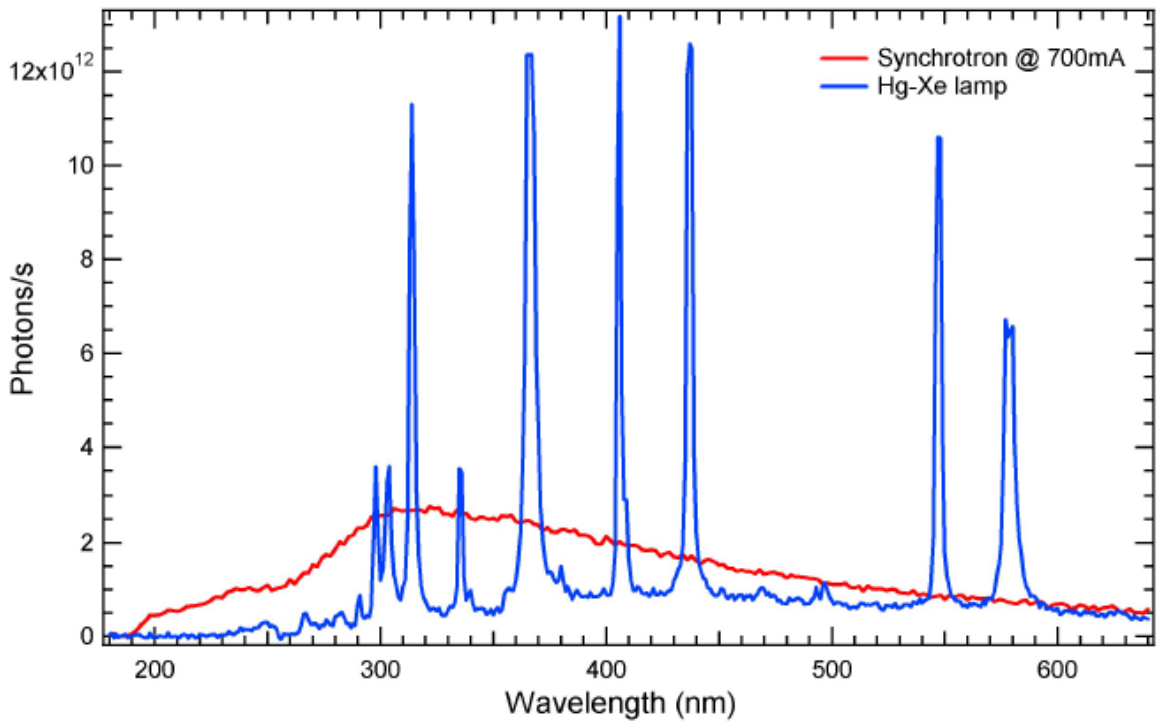
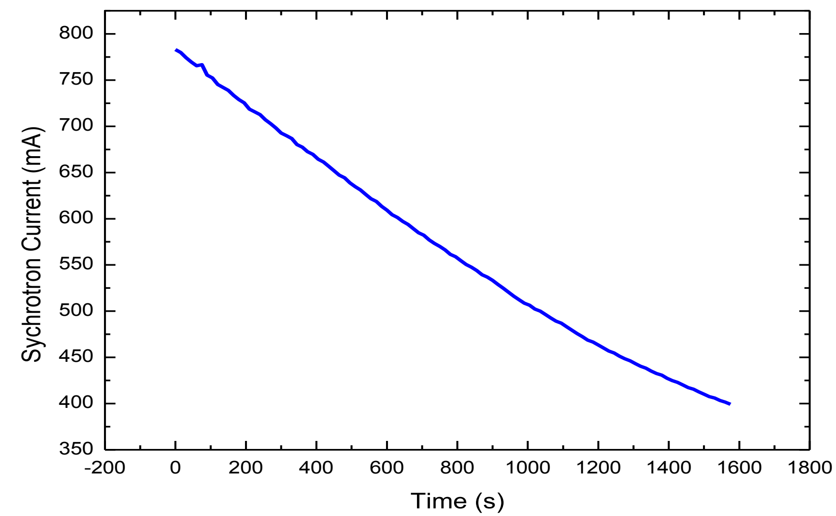
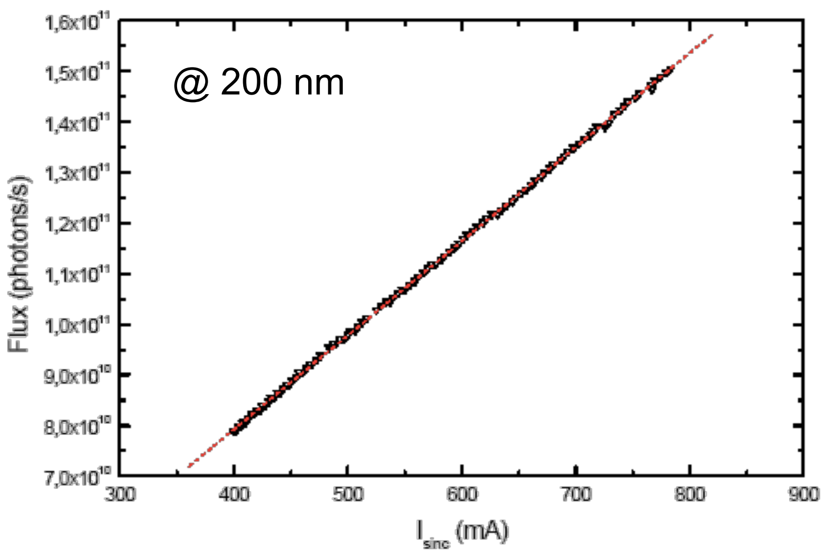


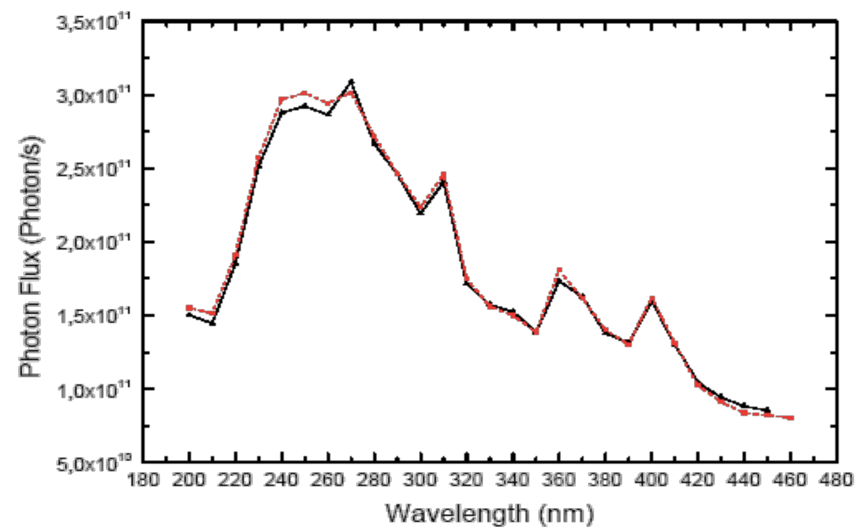
Figure 2. Emission spectrum of the Hamamatsu 500 W Hg-Xe lamp compared to the SR spectrum emitted in the UV-VIS range by an electron current of 0.7 A circulating in the storage ring.

The synchrotron source

I_{norm} = 750 mA







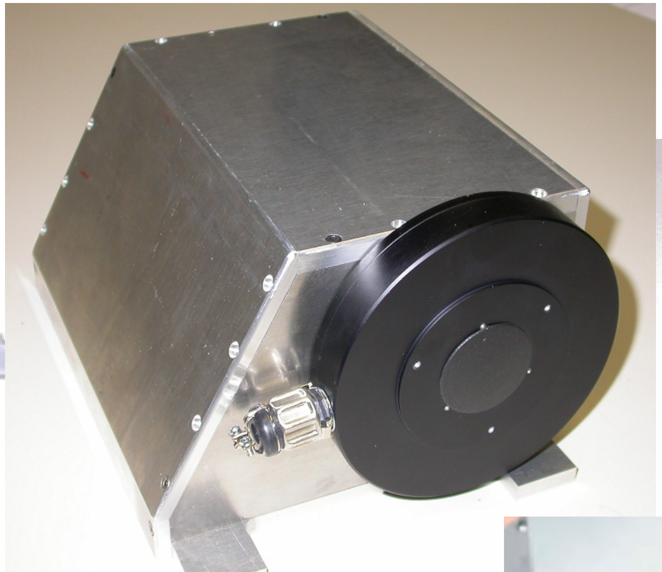
Science

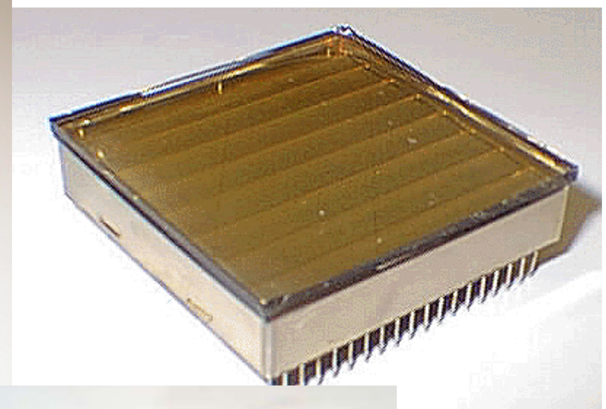
- Particle experiments (using Cherenkov light)
- Astro-particle experiments (using fluorescence light)
- Astronomy experiments
- Space experiments
    - Cosmic rays
    - Astronomy
    - Earth Observation
- Astrobiology and photo-biology
- Photochemistry
- Optical tecnology
- Detector technology
- Instrumentation testing and calibration
- Optical properties of materials

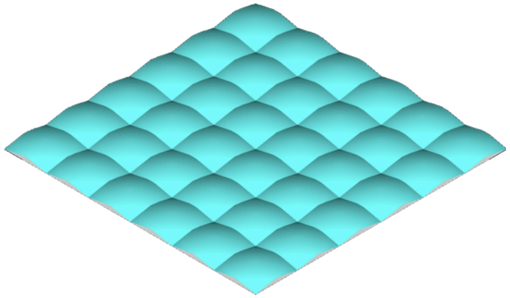
Which science or technology?

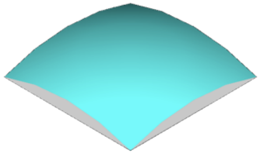
- Electro-optical characterization of optical materials and detectors
- Broad-band and precise spectro-photometry
- ps time-resolved measurement
- UV and VIS polarimetry and spectro-polarimetry
- UV and VIS detector calibration (CCD, MCP, WBM, etc.)
- Experiments on meteorites, micrometeorites and astrobiology
- Photobiology
- Development and tests of innovative detectors and materials (diamond, nanodiamond, carbon nanotubes, nitrides, etc.)
- Test and development of innovative optics and coatings
- UV tracks and background for UHECR
- Test of large optics (ALSO project by ESA)
- AIV and OGSE for space project (EUSO, SCORE/HERSCHEL, WSO/UV)

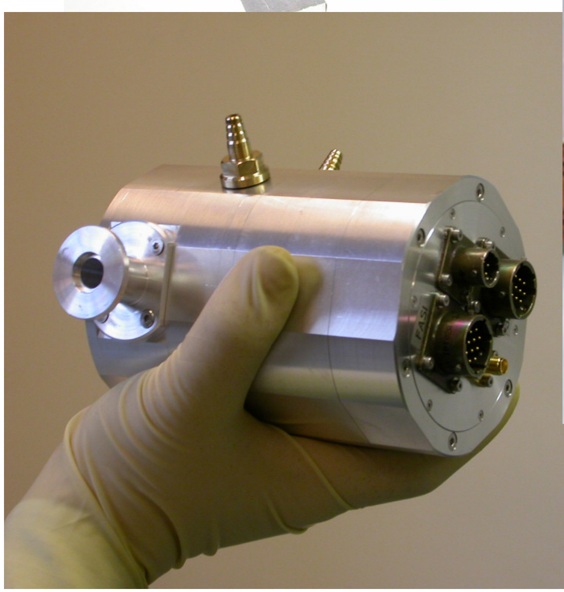
Technologies

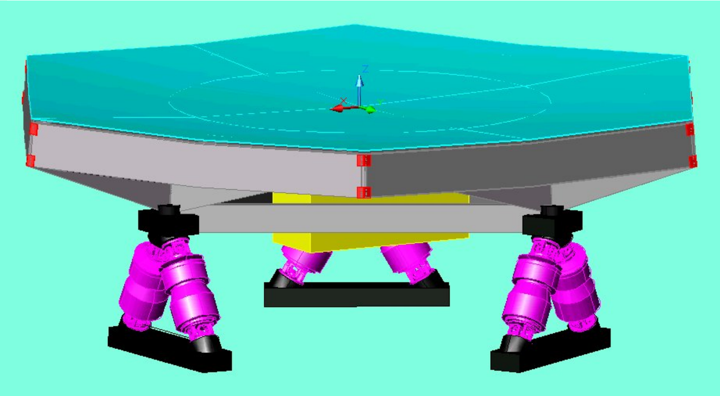




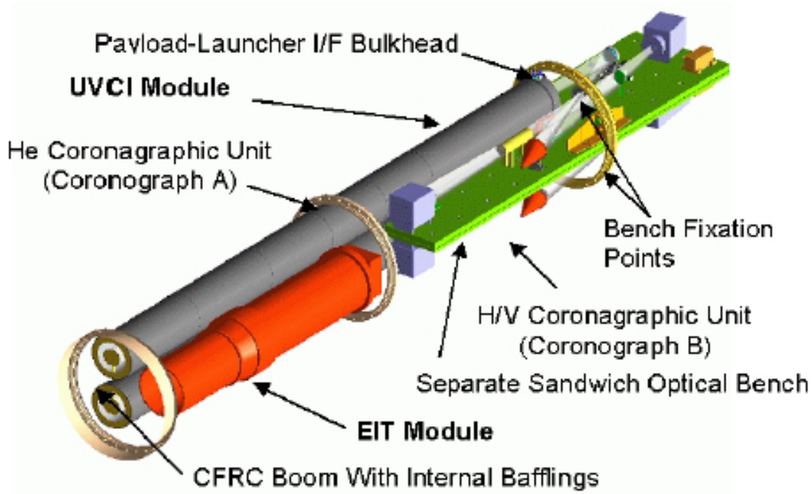


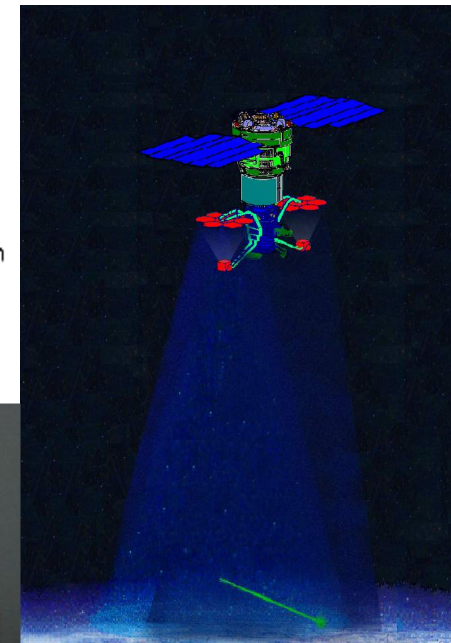


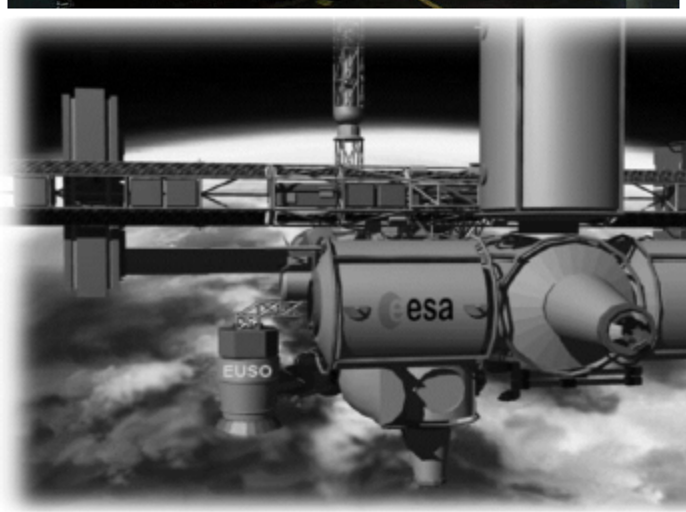


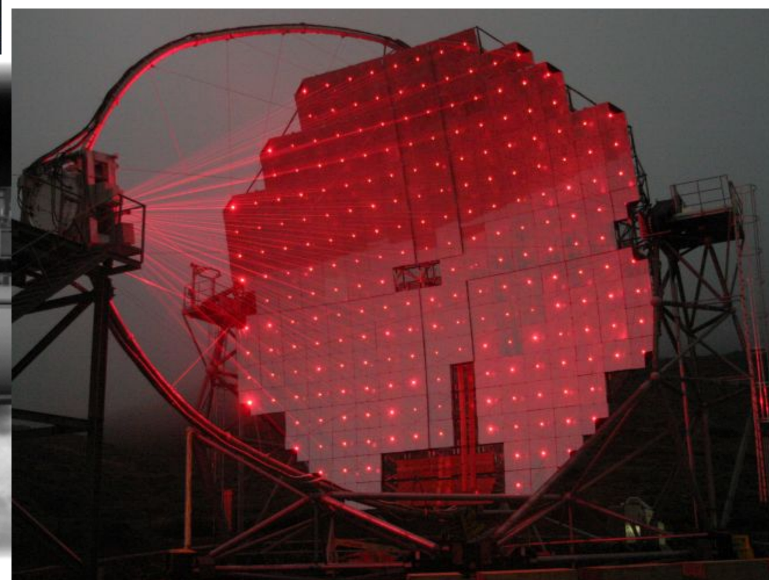


Ground- and space-based experiments



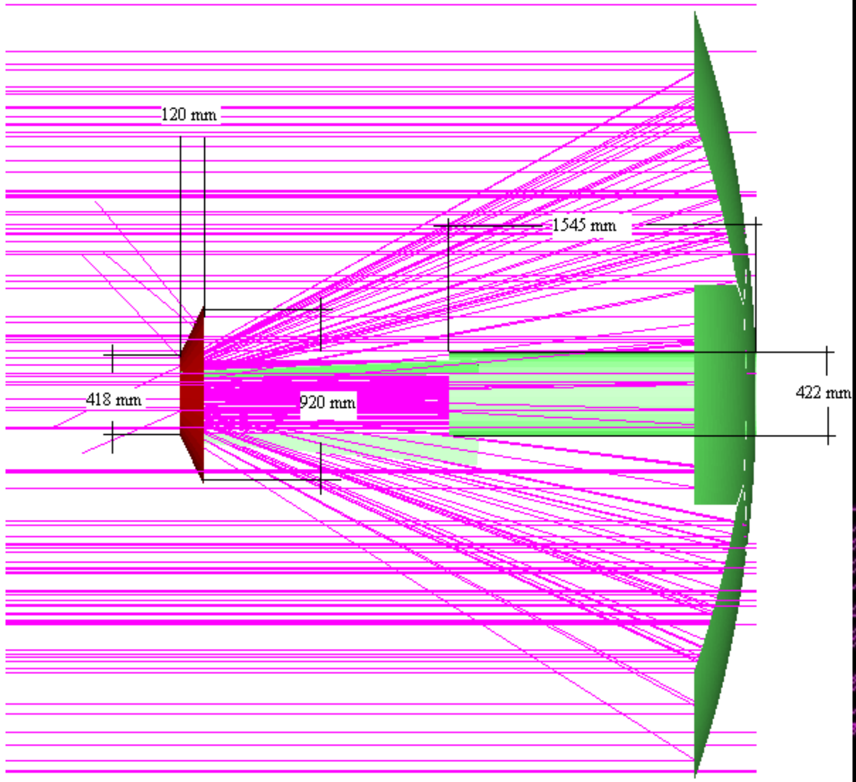


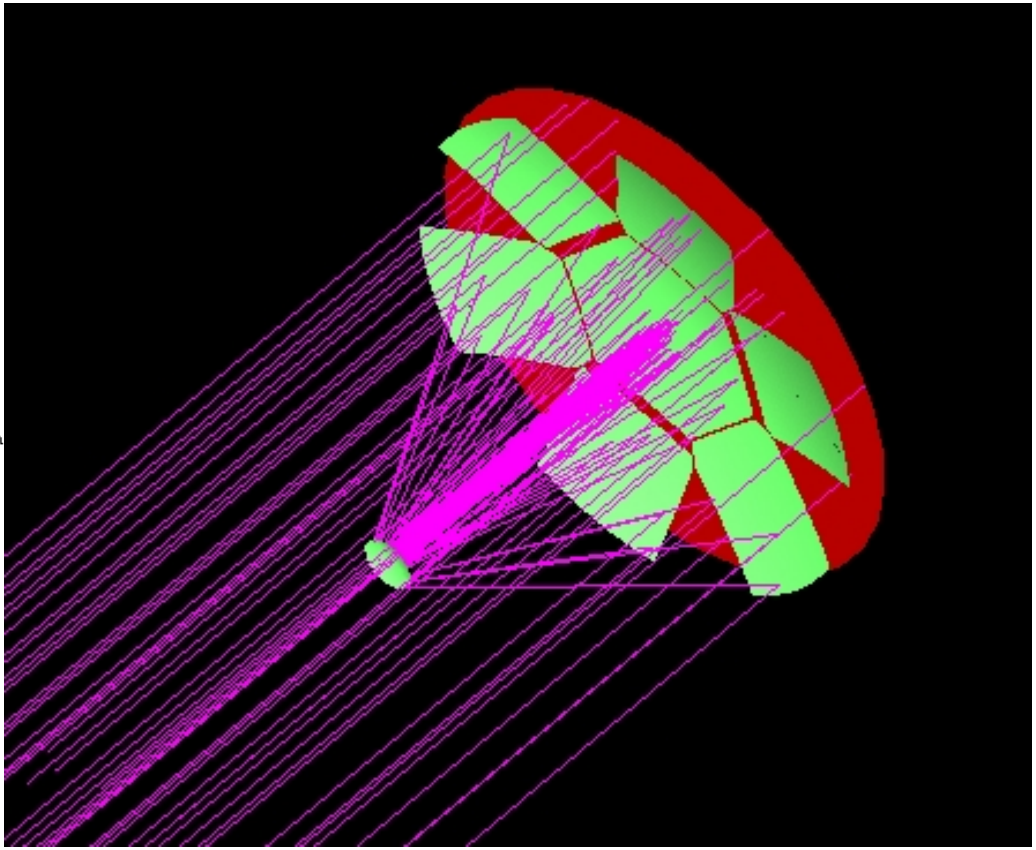




Deployable large mirrors

European Space Agency project





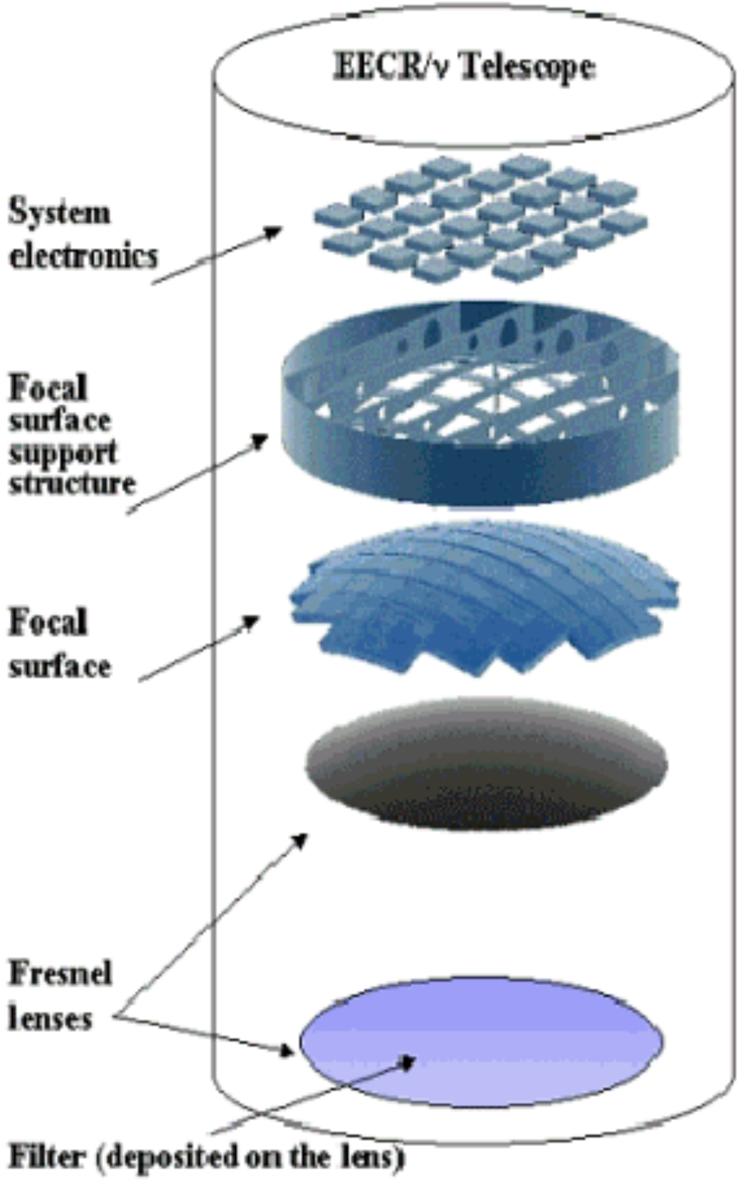
CNR/INO - Arcetri

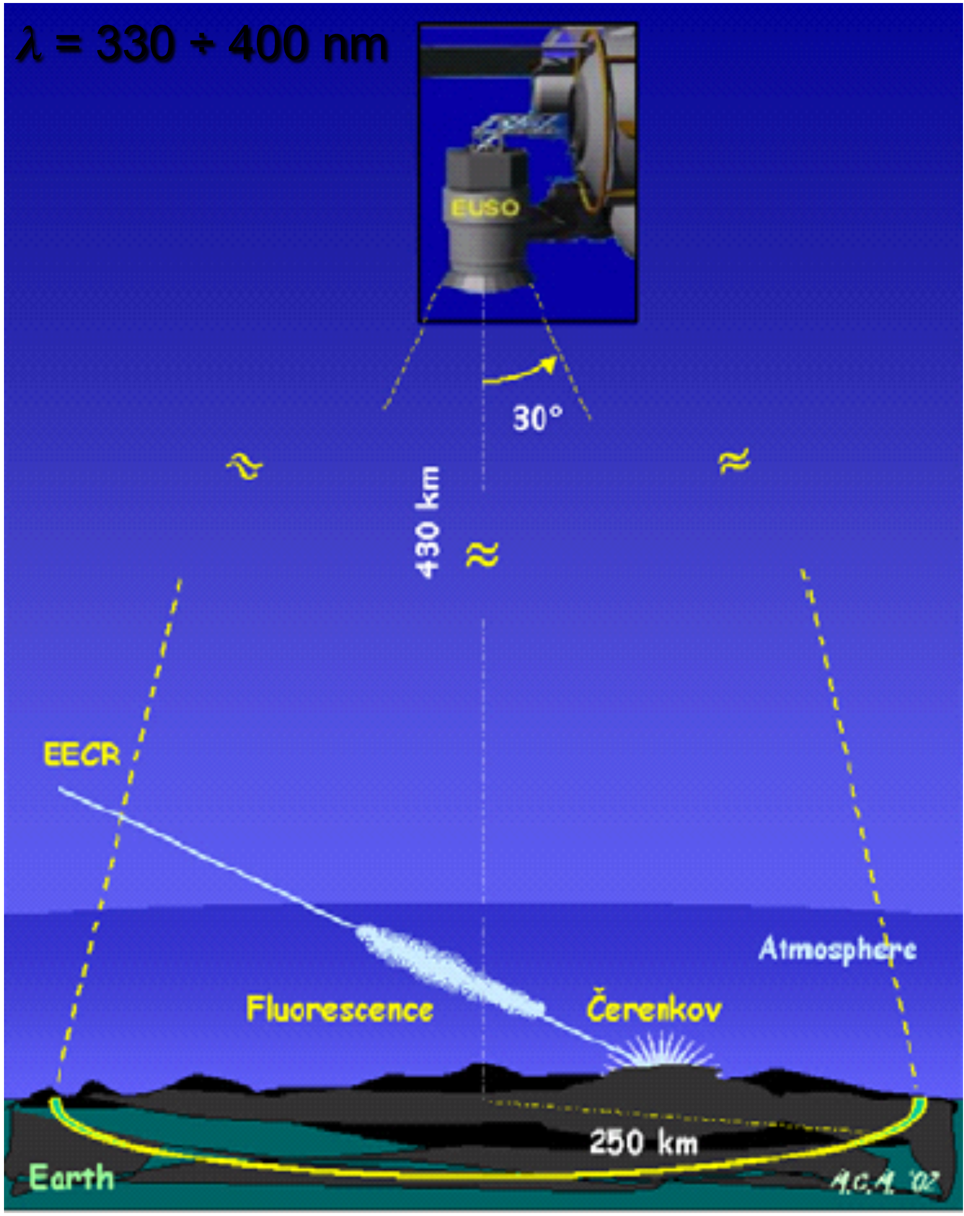
Calibration Experiments for ultrafast UV transients

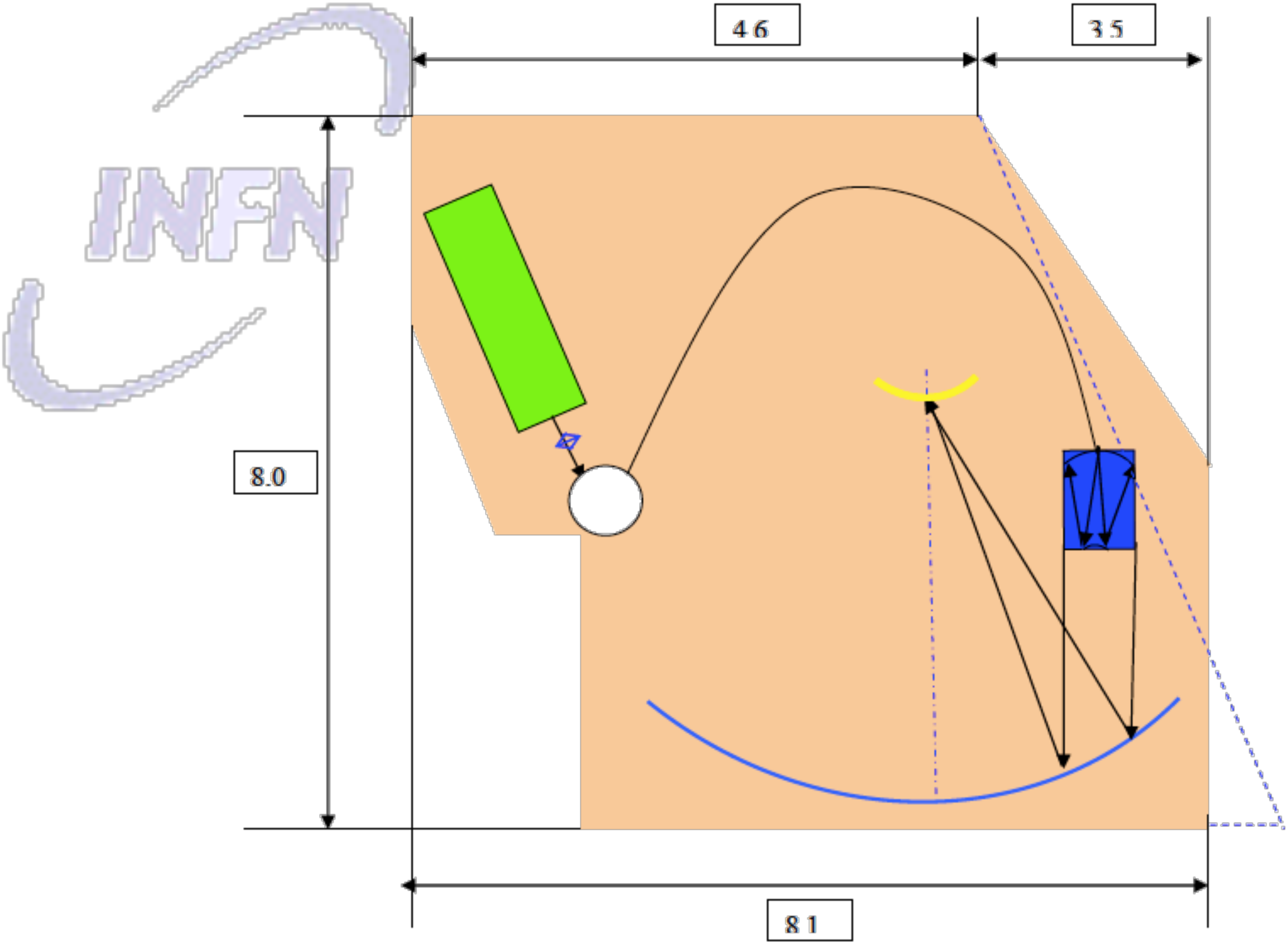
The UHECR detection through the UV fluorescence emission is mainly a technological.

- SOURCE is a support equipment facing the development of highly-sensitive optical and detection innovative technologies (mirror size up to 4 m).
- SOURCE is a facility that allow for the first time the real simulation of fluorescence UV tracks against a background in order to test the performance of UHECR ground- and space-based instrumentation in fully operative conditions.

EUSO


EECR/ν Telescope
System electronics
Focal surface support structure
Focal surface
Fresnel lenses
Filter (deposited on the lens)


λ = 330 ÷ 400 nm
EUSO
30°
430 km
EECR
Atmosphere
Fluorescence
Čerenkov
250 km
Earth

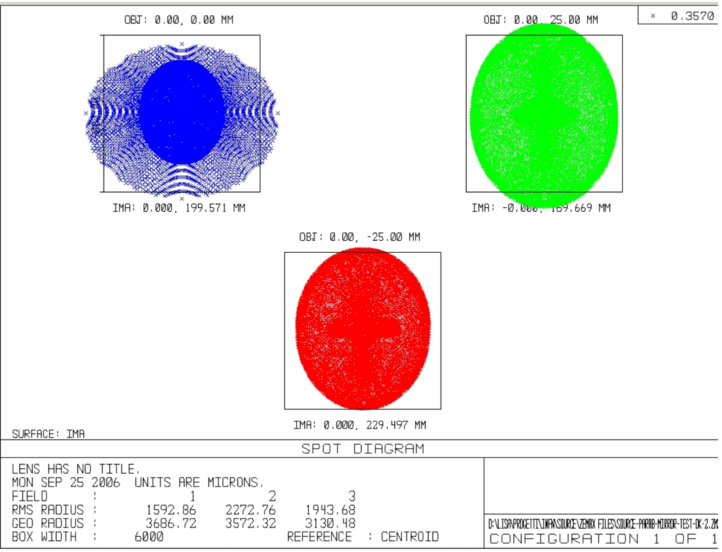


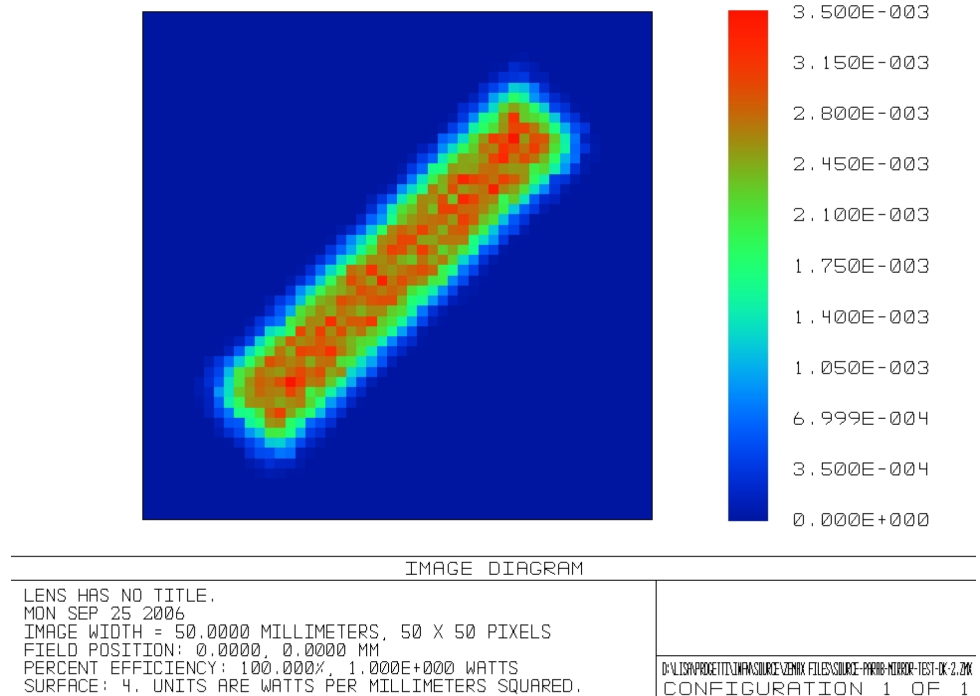
4.6
3.5
8.0
8.1

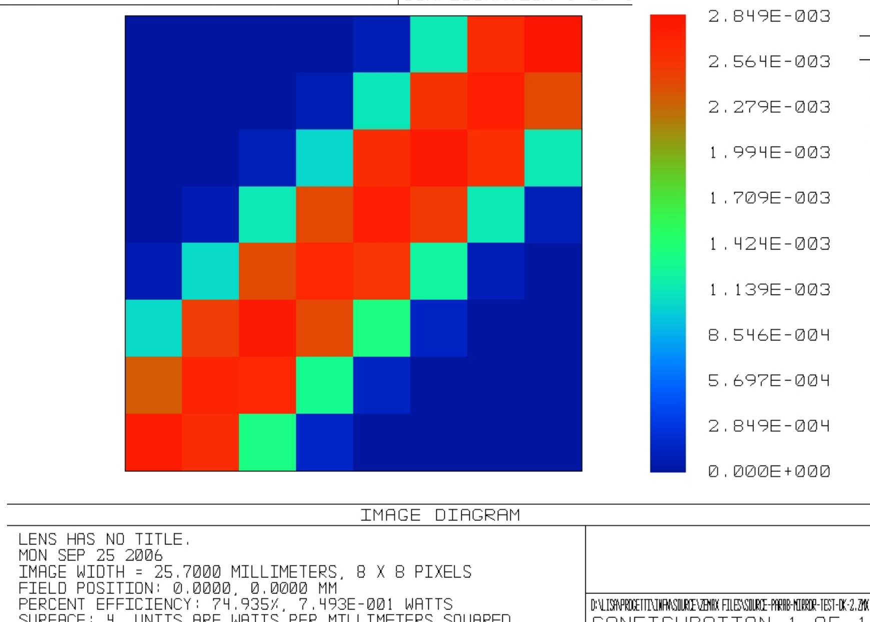
Specifiche per il layout ottico

- Produrre tracce con sviluppo temporale minimo di 300 μs
- Larghezza di banda 300-400 nm
- Produrre un background di luce diffusa
- Larghezza di banda 200-650 nm
- Flessibilità per misurare specchi con differenti caratteristiche ottiche
- Possibilità di misurare ottiche in trasmissione

Schmidt da 4 metri

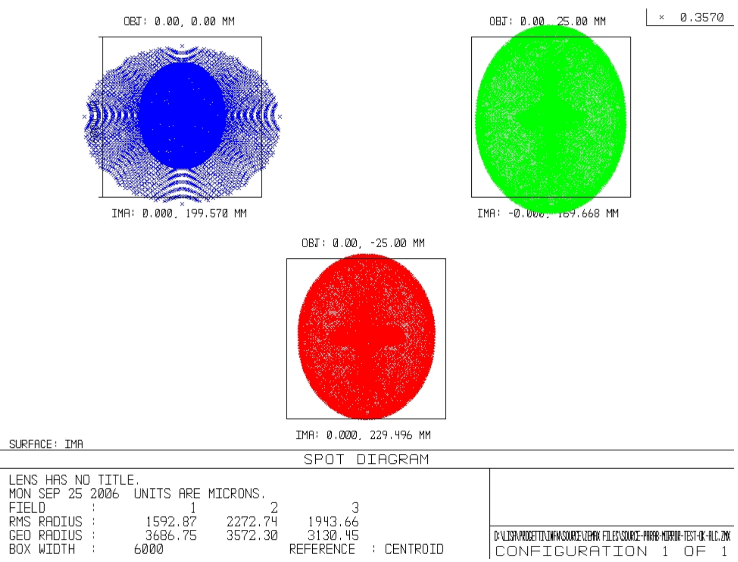


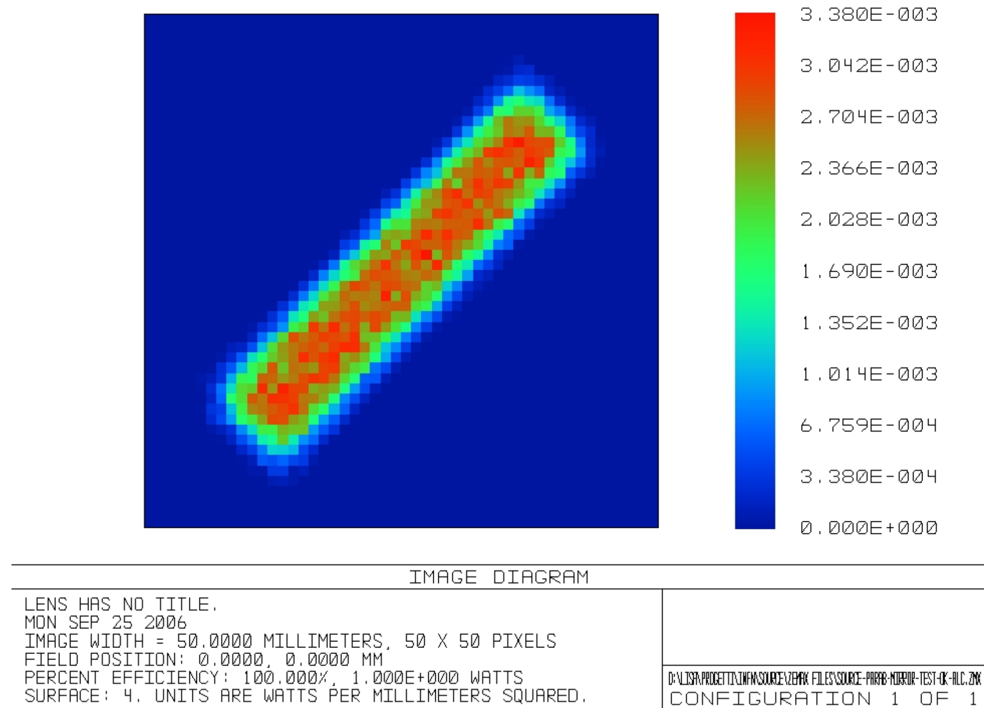


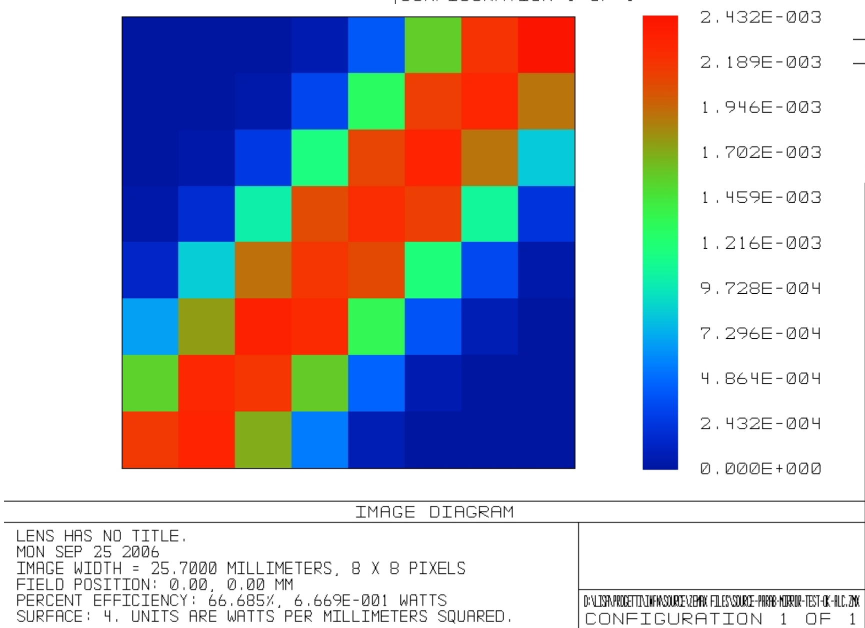


1

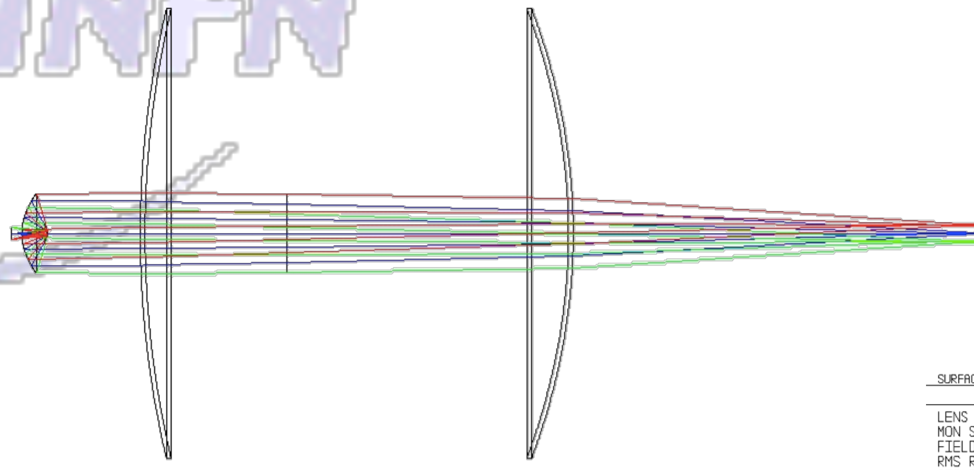
Schmidt ALC da 1 metro

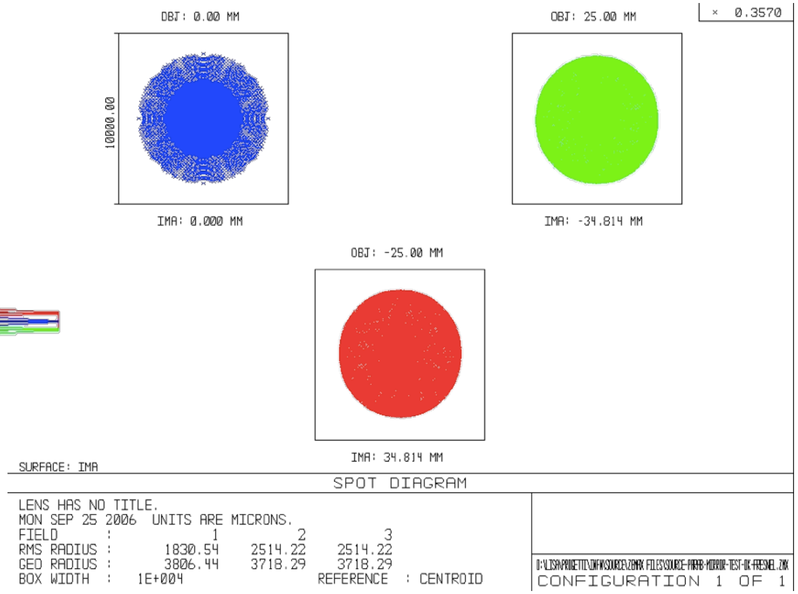


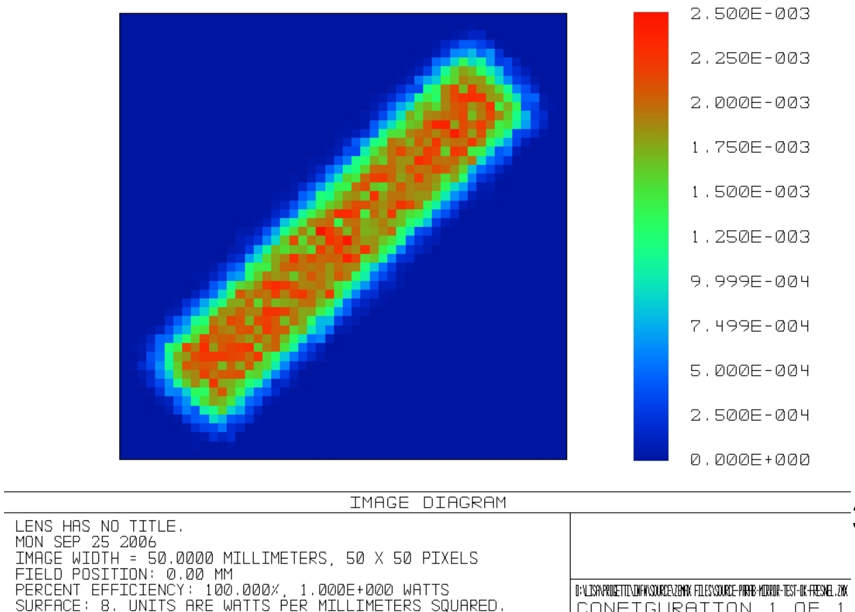


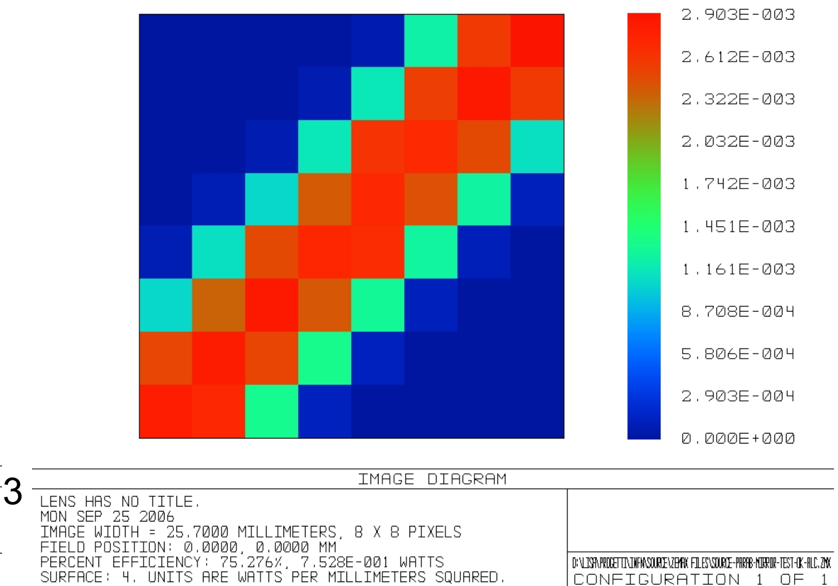


EUSO: Lenti di Fresnel

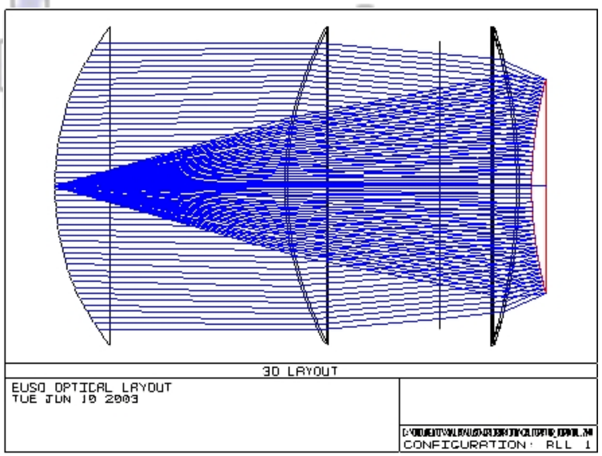


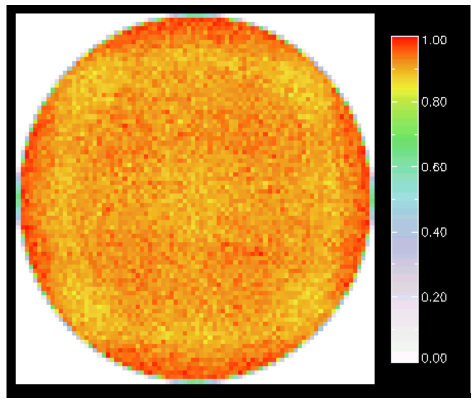


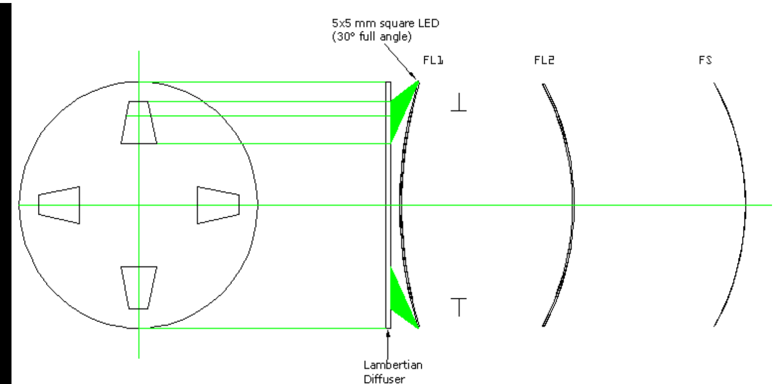


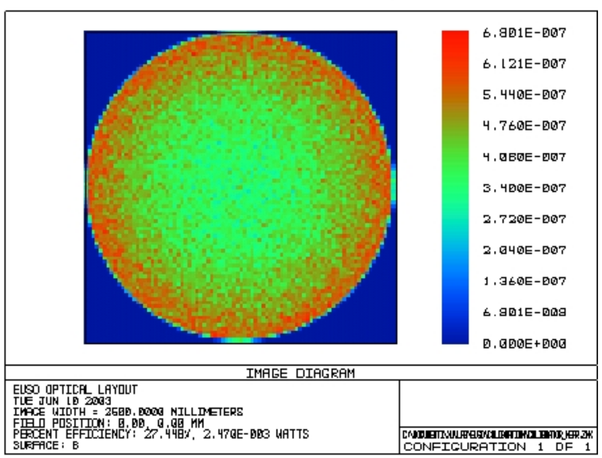


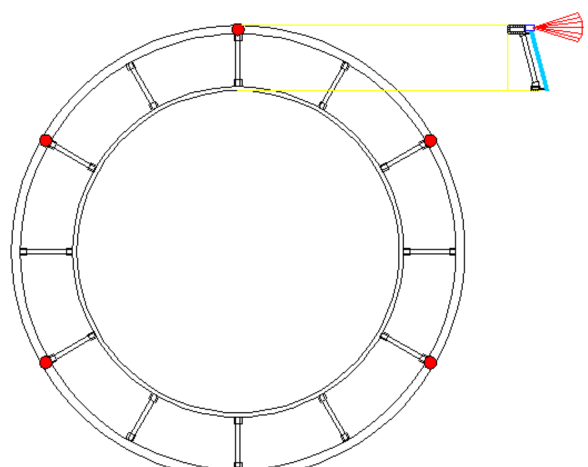
In-flight calibration

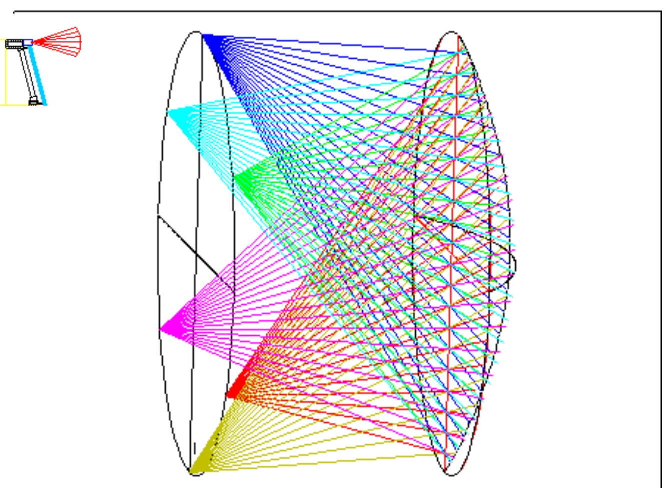




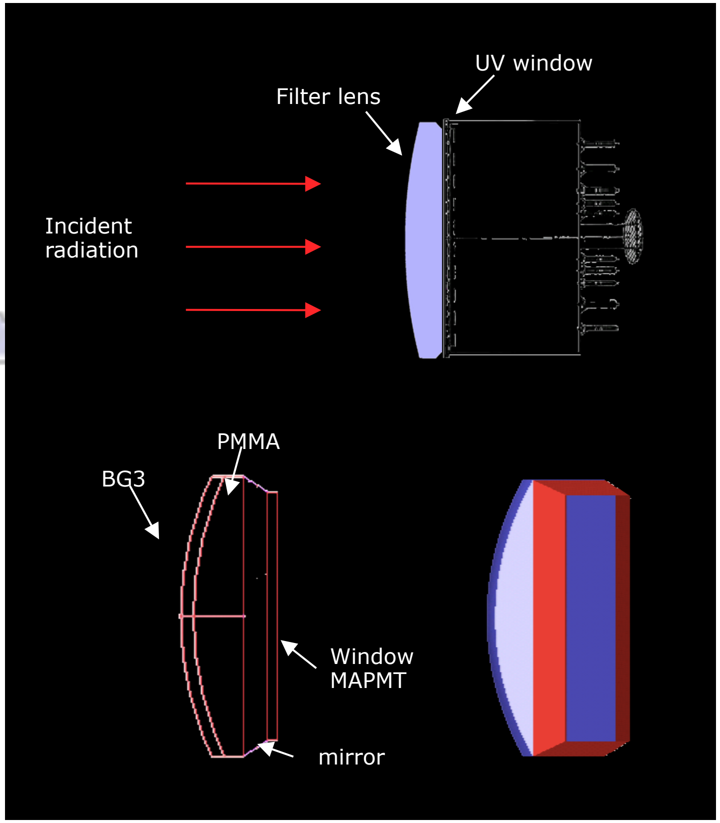


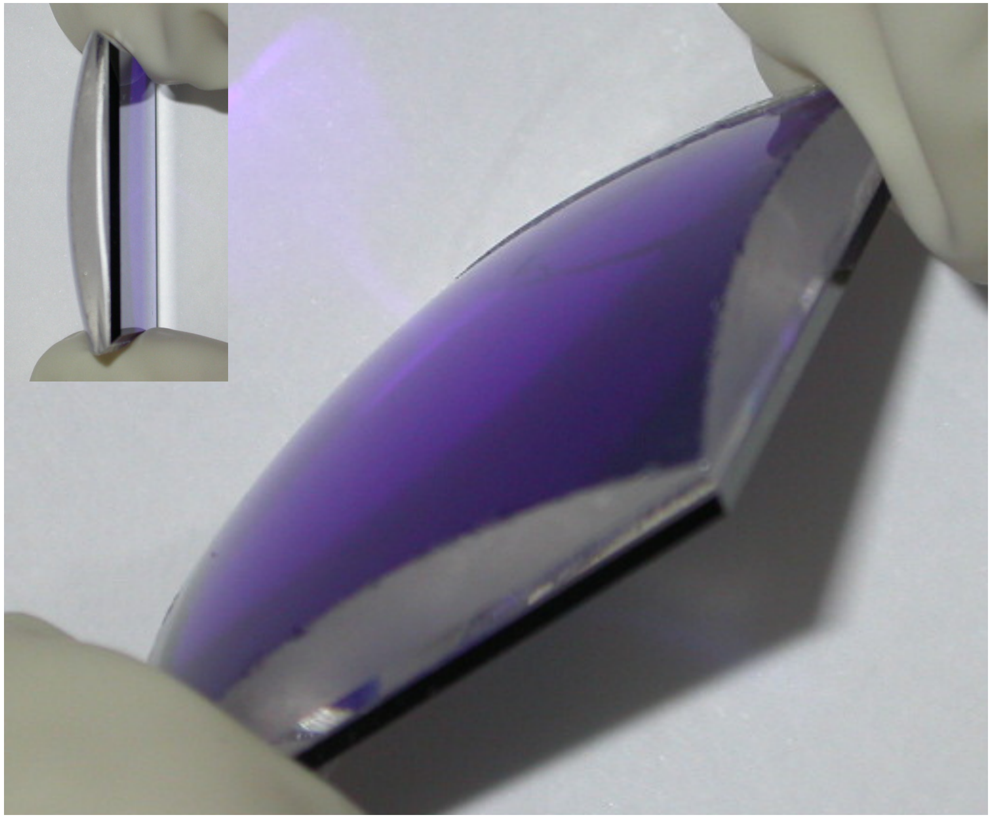






Optical adapters

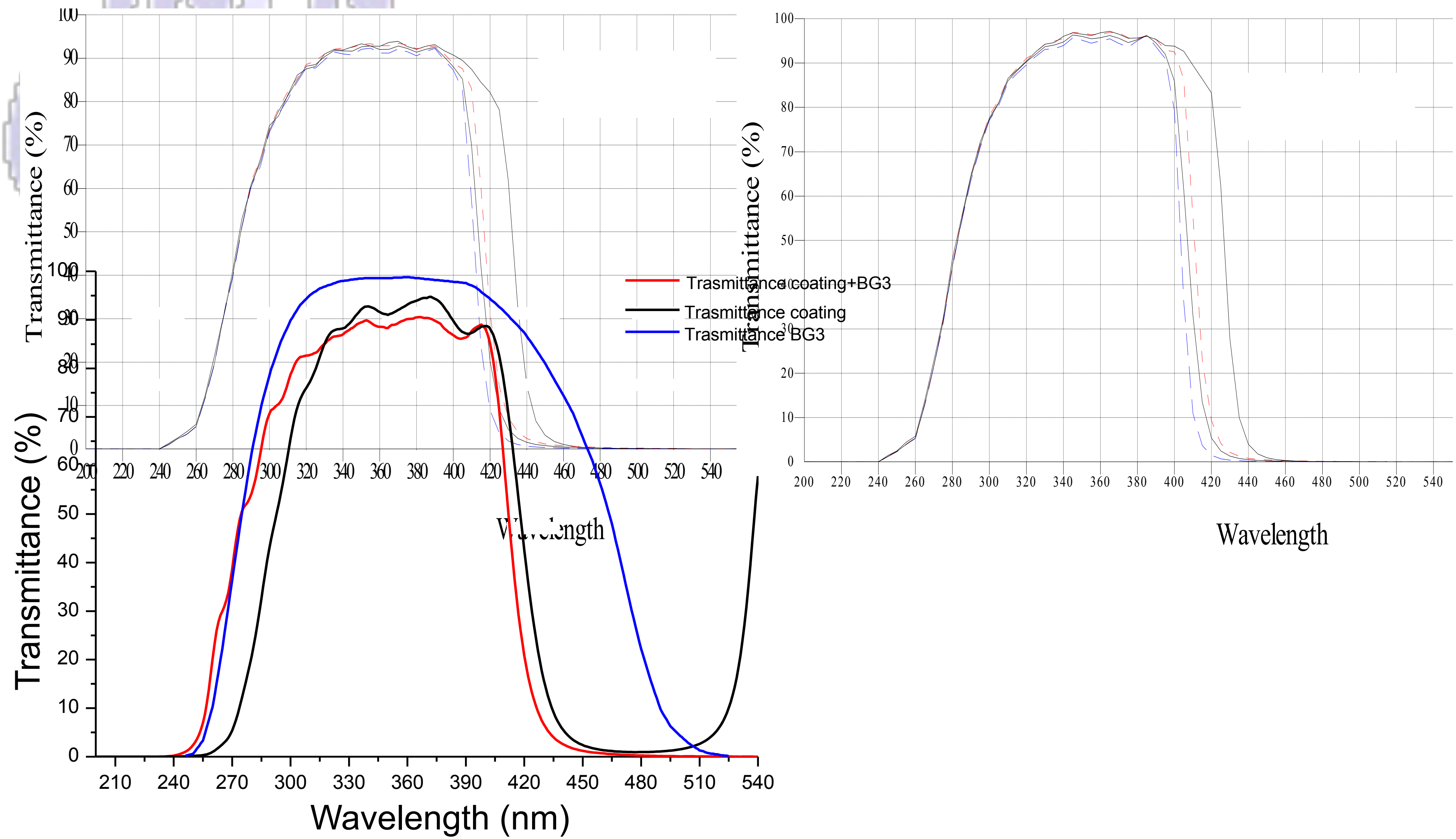




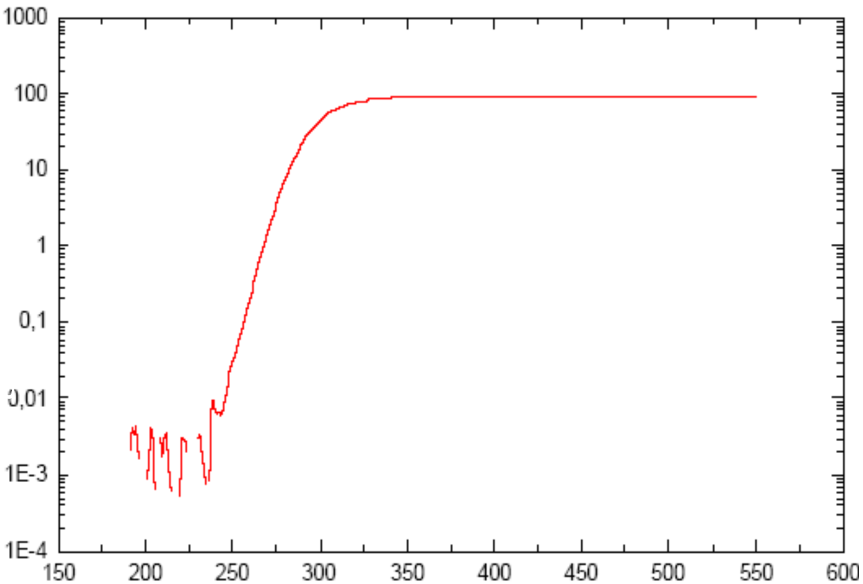
Weight of single lens	Total Weight
3.74 g	20.7 kg

λ (nm)	Geometric Efficiency (%)	Radiometric Efficiency (%)
337	99.5	94.7
357	99.5	95.6
391	99.5	94.4

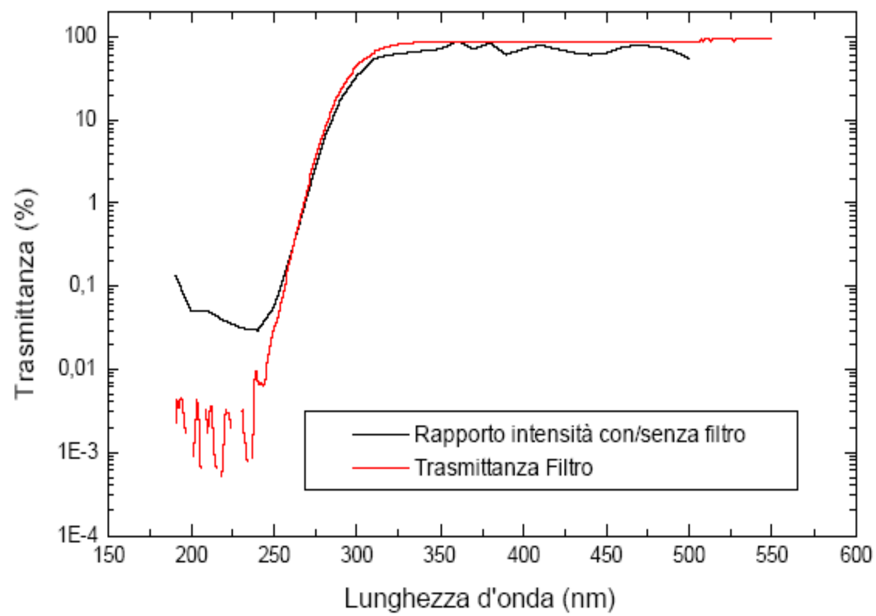
Innovative filters and coatings



Spectro-photometry

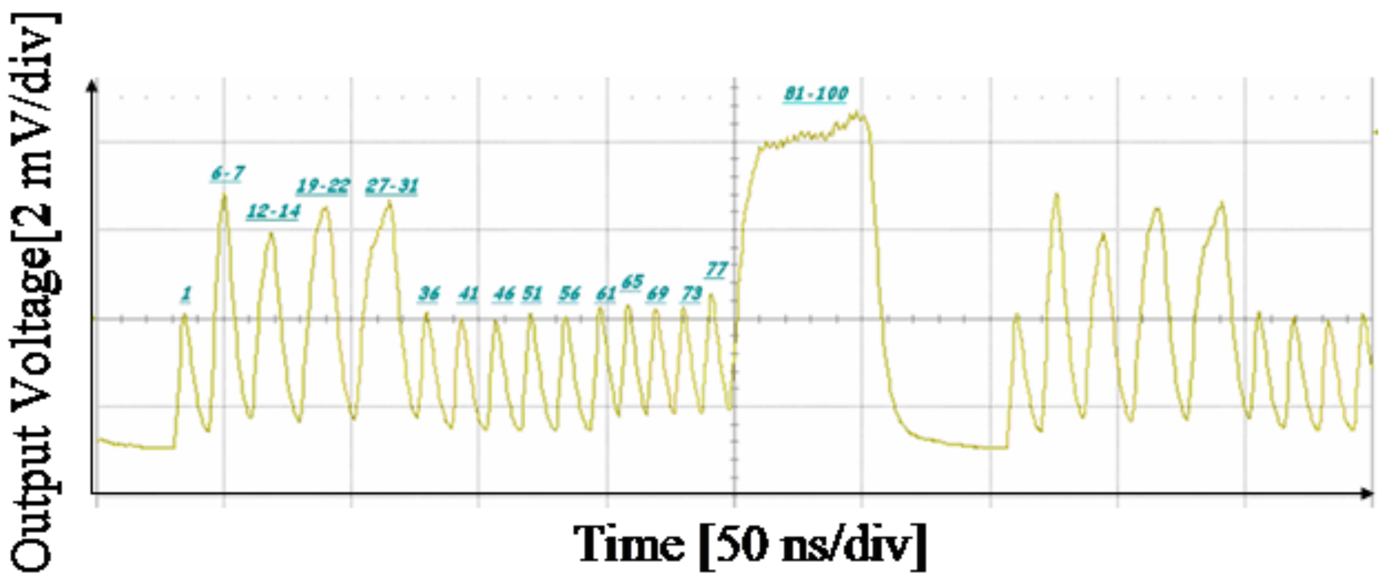


$$T_{\lambda} = \frac{I_{\lambda}}{I_{(\lambda o)}}$$

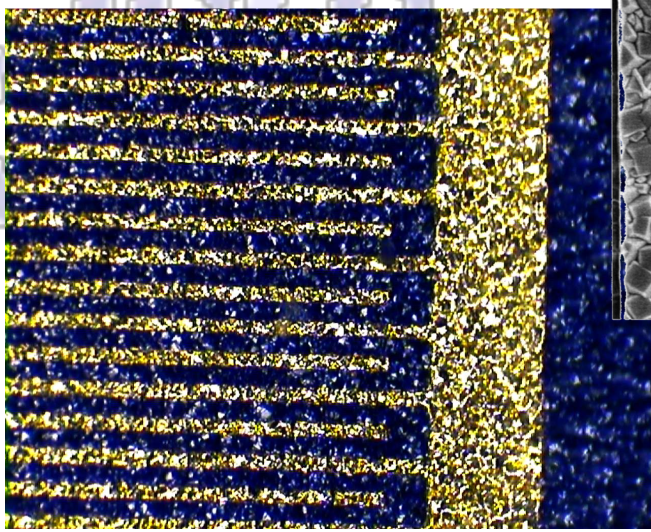


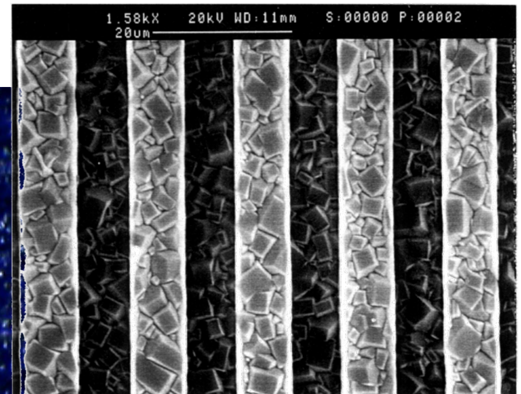
Technique to measure response time

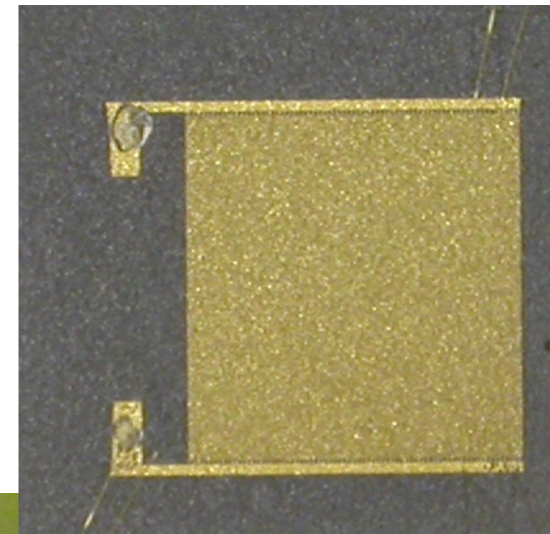
1	2	3	4	5	**6**	**7**	8	9	10	11	**12**	**13**	**14**	15	16	17	18	**19**	**20**
21	**22**	23	24	25	26	**27**	**28**	**29**	**30**	**31**	32	33	34	35	**36**	37	38	39	40
41	42	43	44	45	**46**	47	48	49	50	**51**	52	53	54	55	**56**	57	58	59	60
61	62	63	64	**65**	66	67	68	**69**	70	71	72	**73**	74	75	76	**77**	78	79	80
81	**82**	**83**	**84**	**85**	**86**	**87**	**88**	**89**	**90**	**91**	**92**	**93**	**94**	**95**	**96**	**97**	**98**	**99**	**100**
101	102	103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120

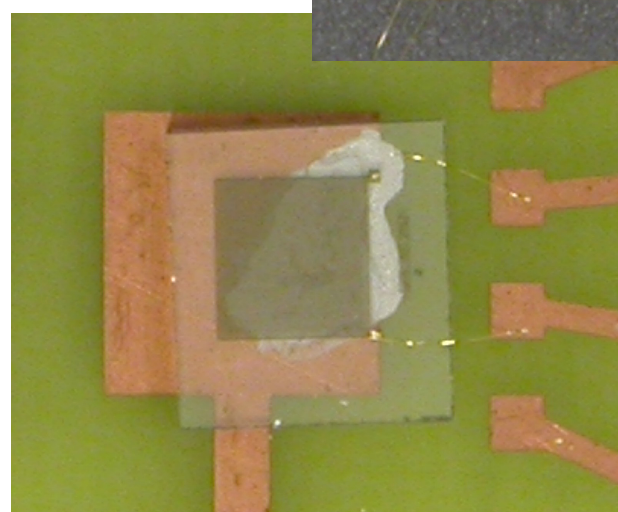


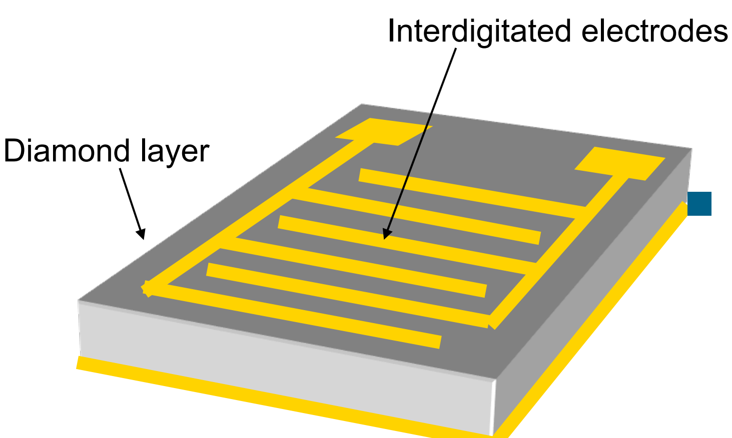
UV diamond photodetectors

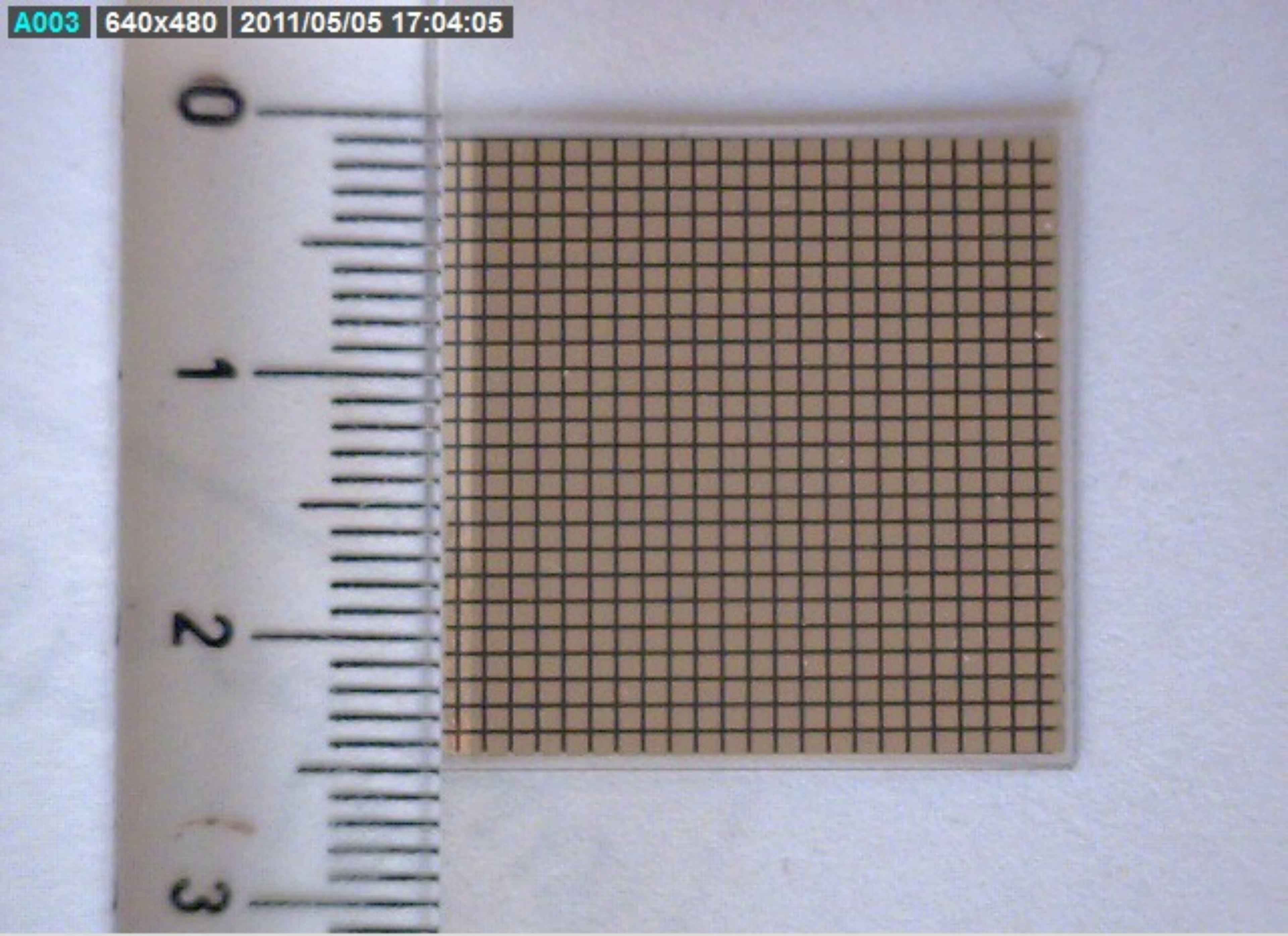




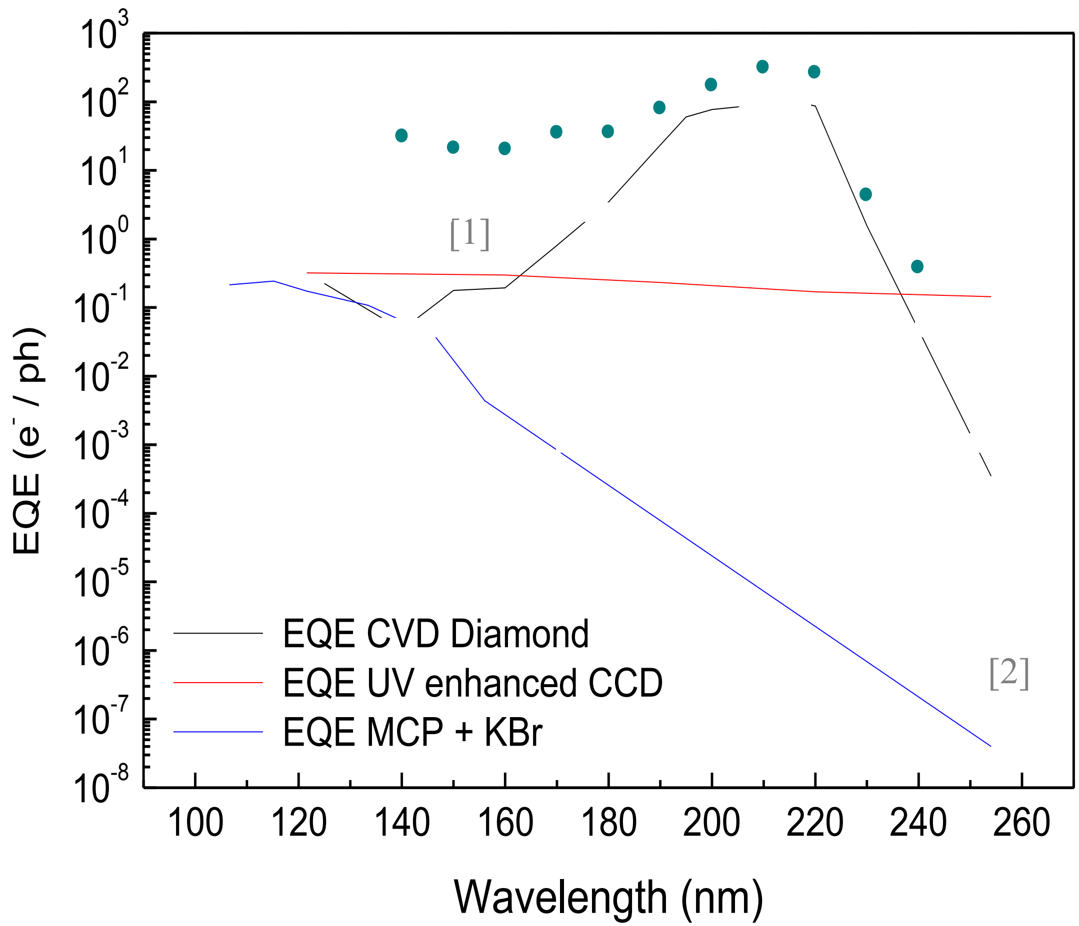







A003
640x480
2011/05/05 17:04:05
0
1
2
3

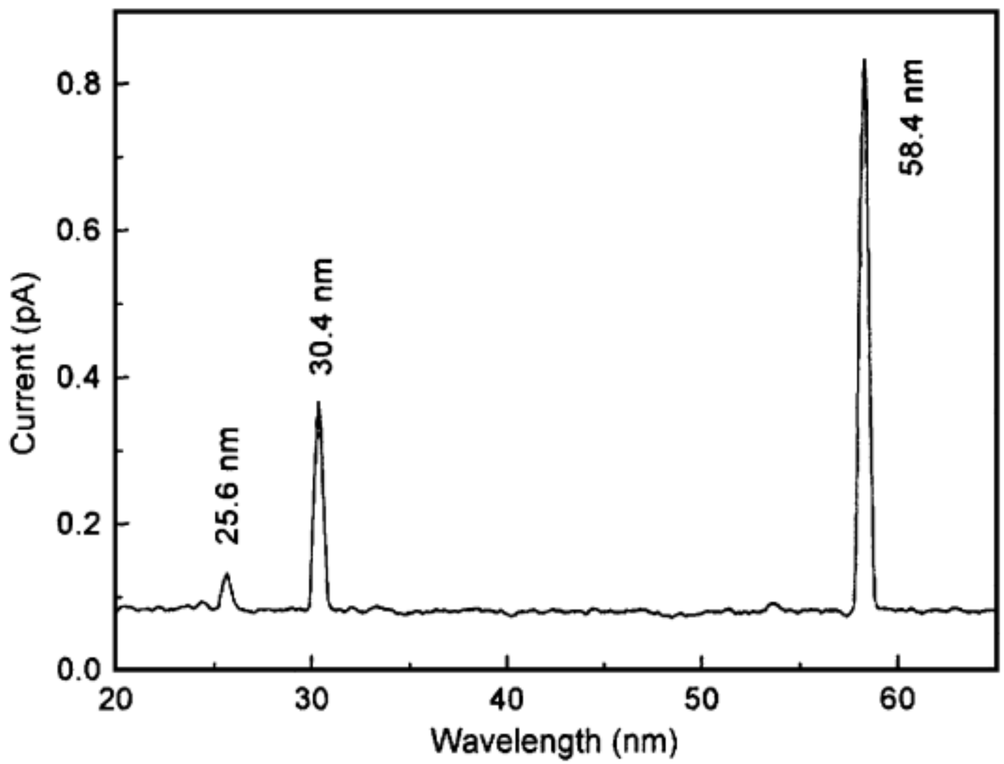
Diamond detectors
Confronto

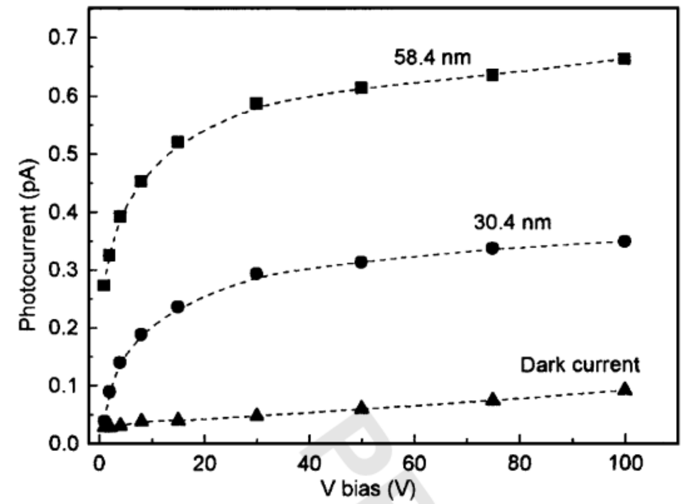


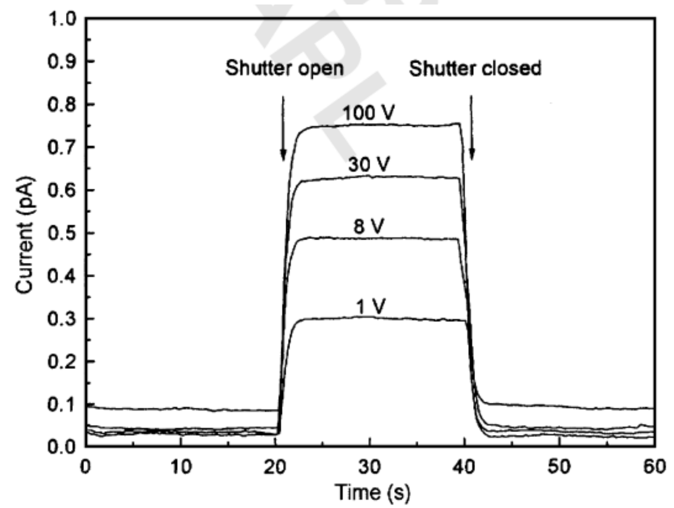
[1] Naletto, Pace et al, 1994

[2] Wilhelm et al.,1995

Diamond detectors
VUV response

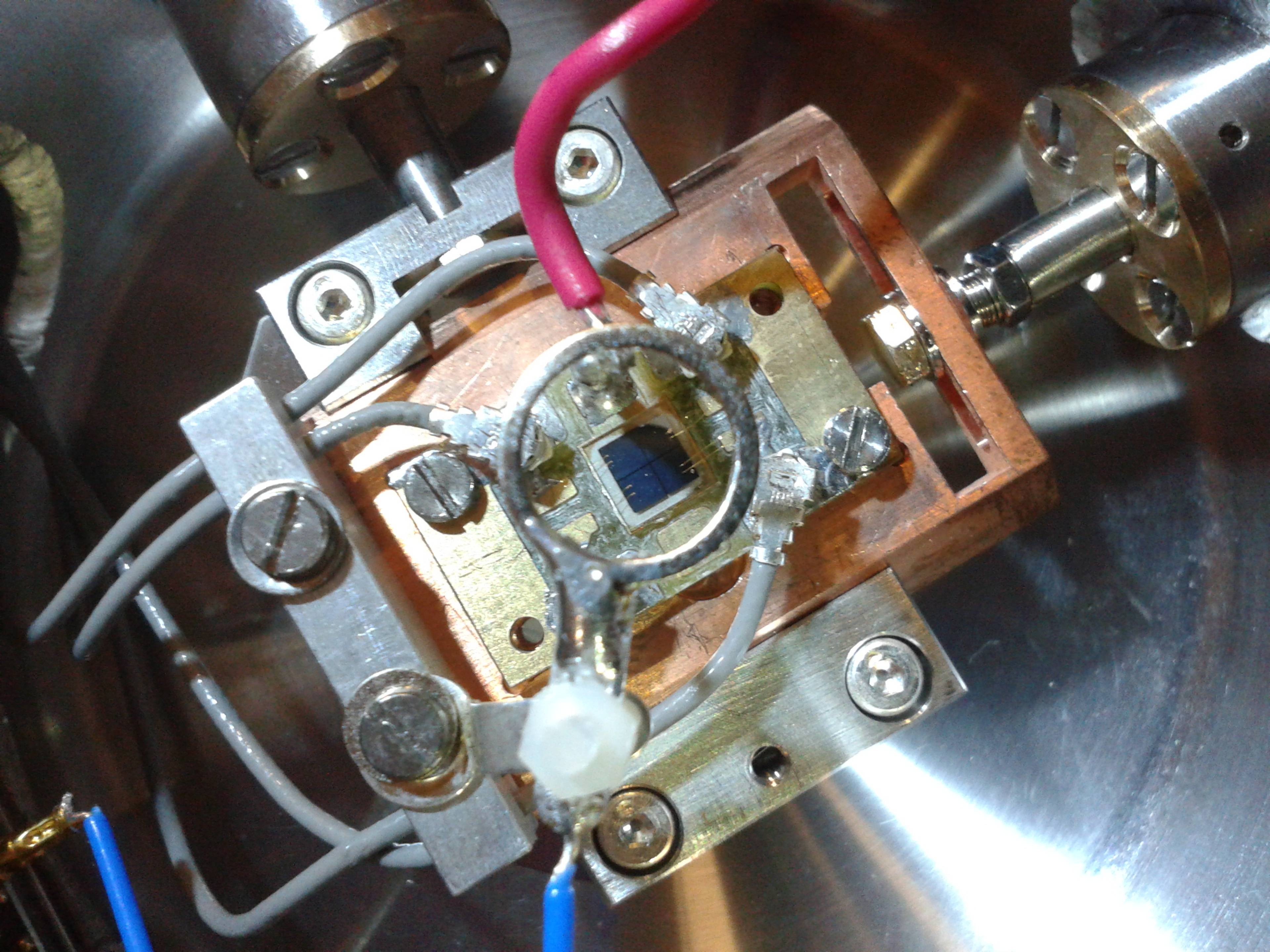


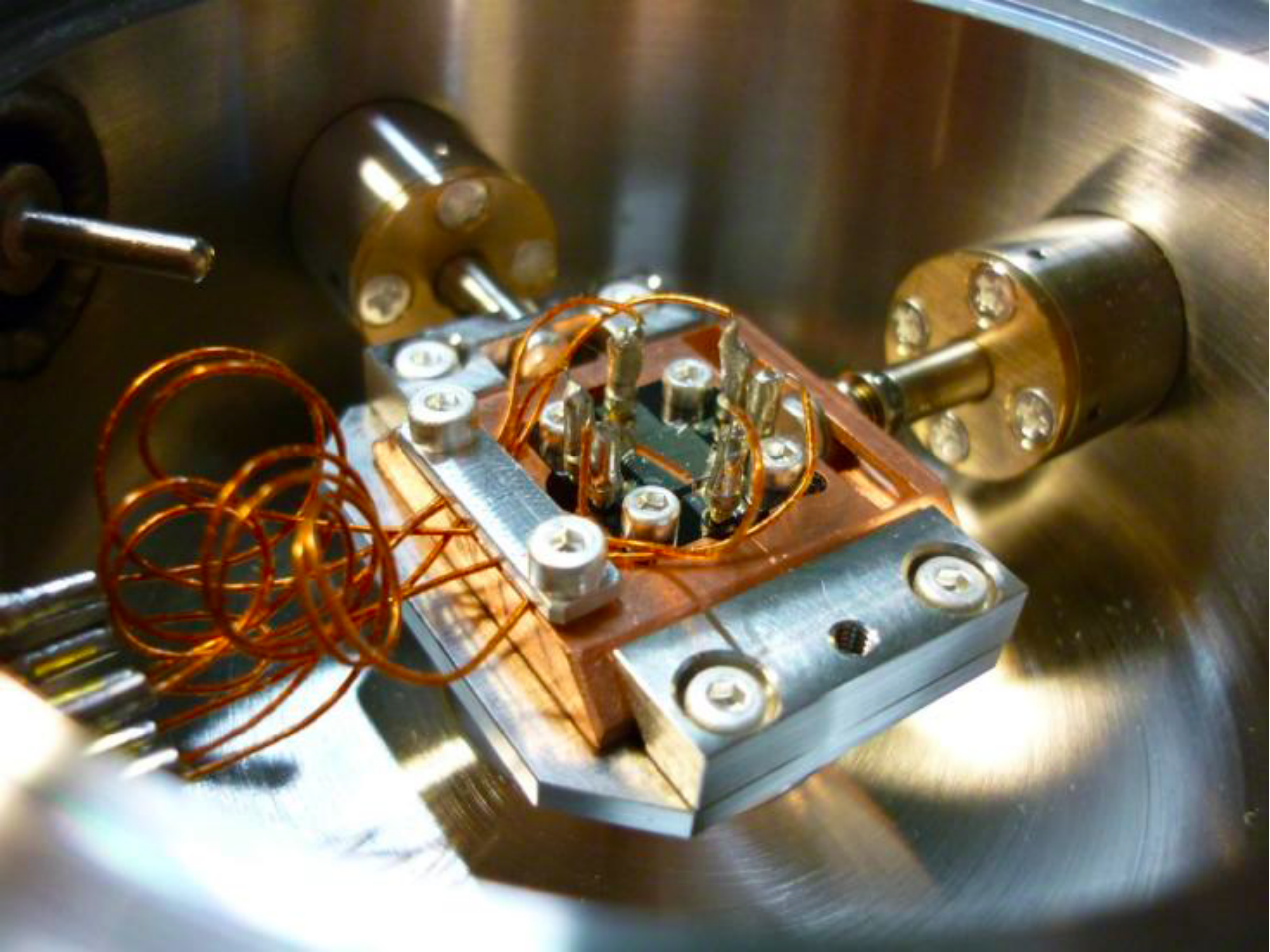




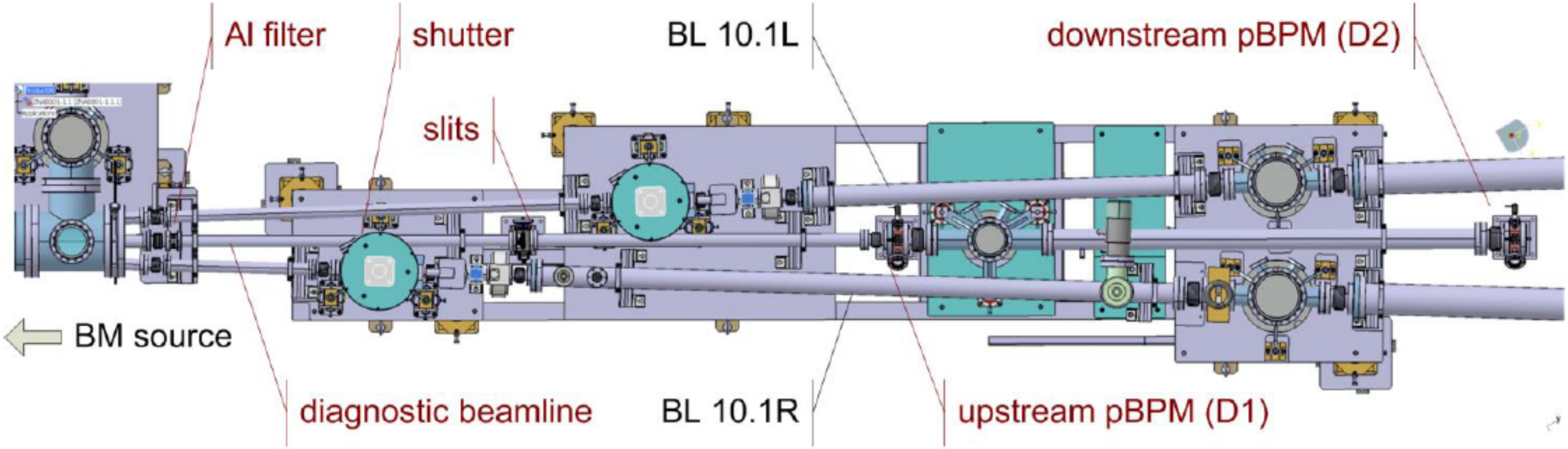
Scopo

Development of ultrafast X-UV diamond detectors for FEL and SR applications

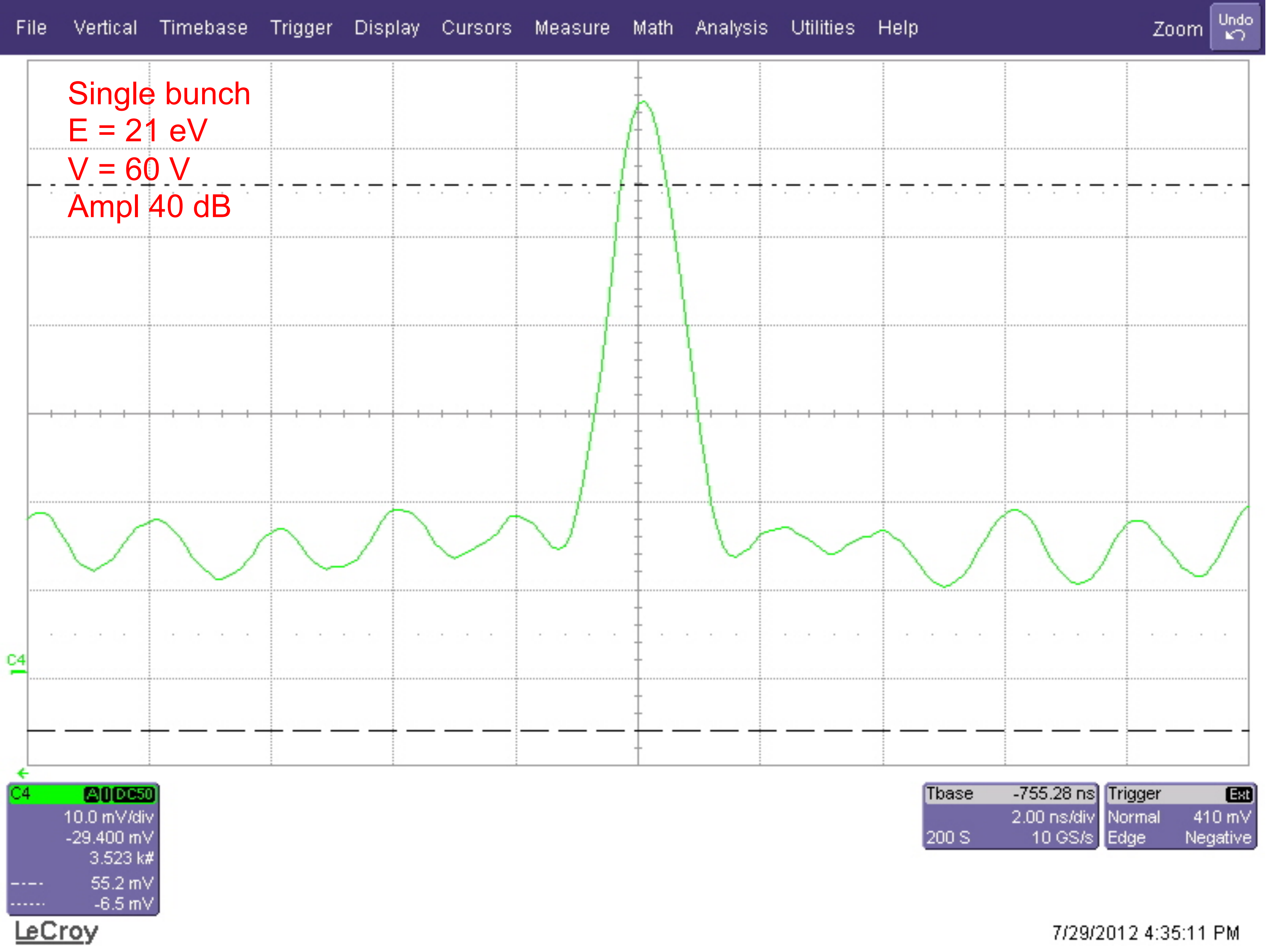


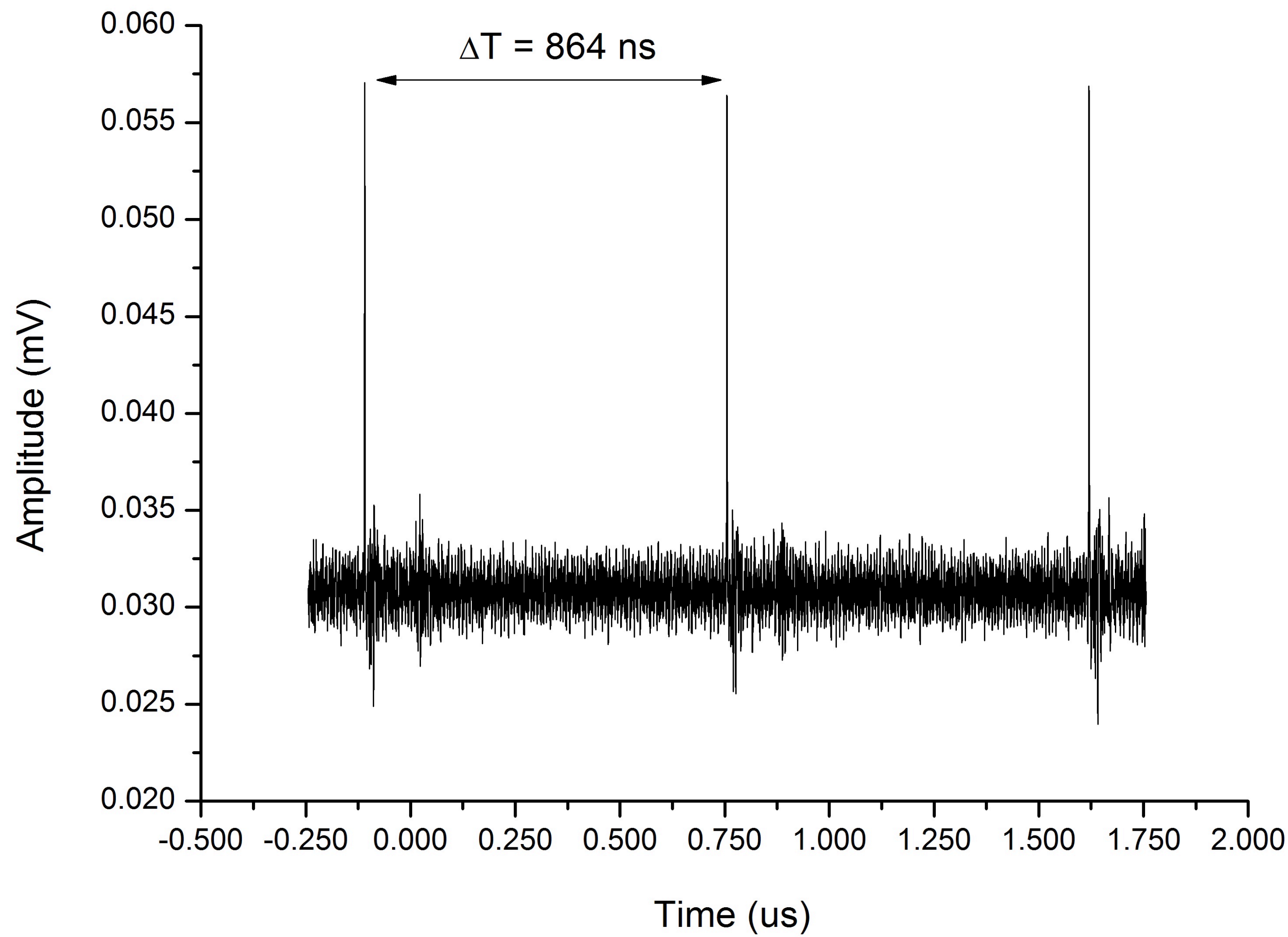


pBPM



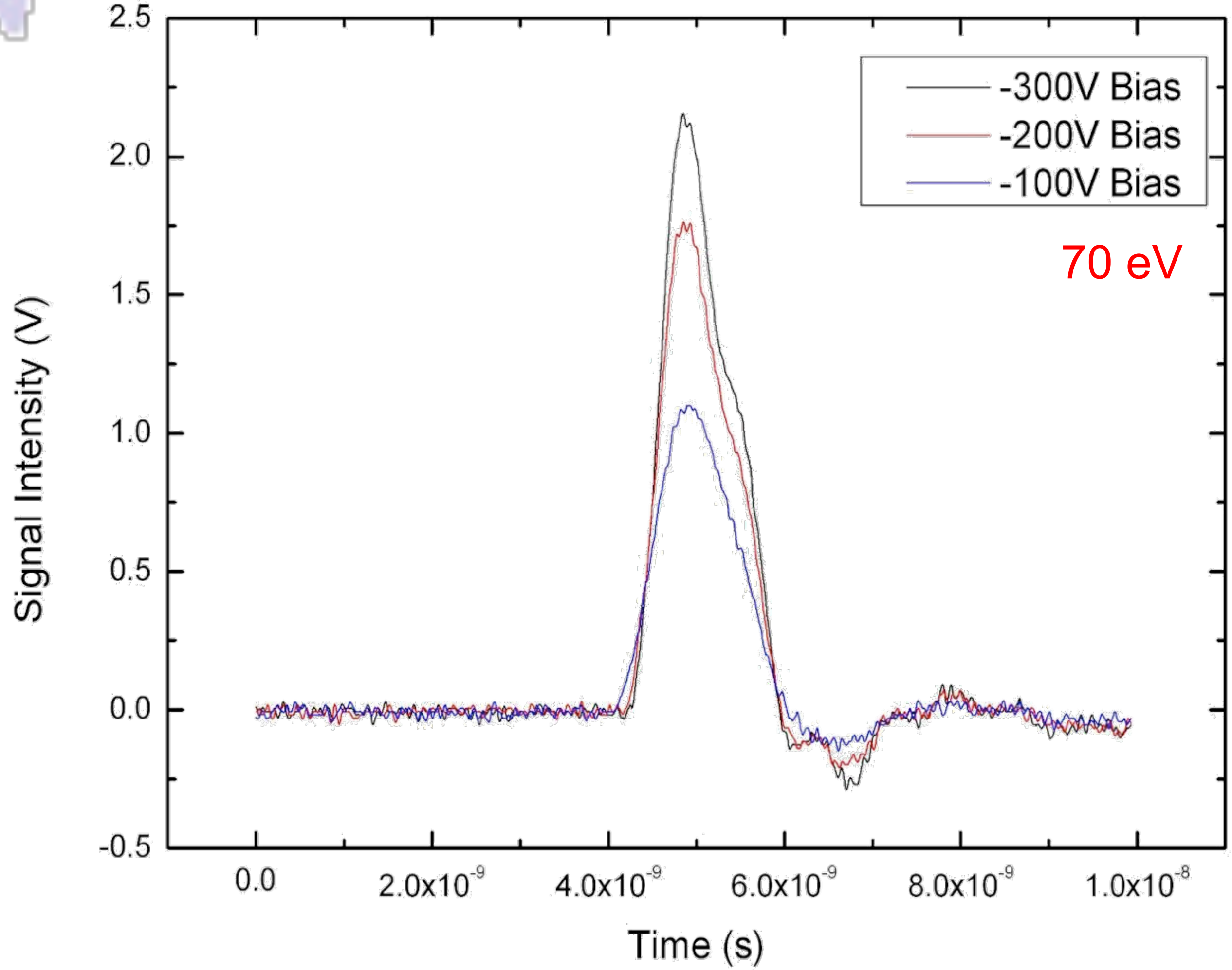
Al filter
shutter
BL 10.1L
downstream pBPM (D2)
slits
BM source
diagnostic beamline
BL 10.1R
upstream pBPM (D1)


File
Vertical
Timebase
Trigger
Display
Cursors
Measure
Math
Analysis
Utilities
Help
Zoom
Undo
Single bunch
E = 21 eV
V = 60 V
Ampl 40 dB
C4
C4
DC50
10.0 mV/div
-29.400 mV
3.523 k#
55.2 mV
-6.5 mV
Tbase -755.28 ns
2.00 ns/div
200 S 10 GS/s
Trigger Ext
Normal 410 mV
Edge Negative
LeCroy
7/29/2012 4:35:11 PM

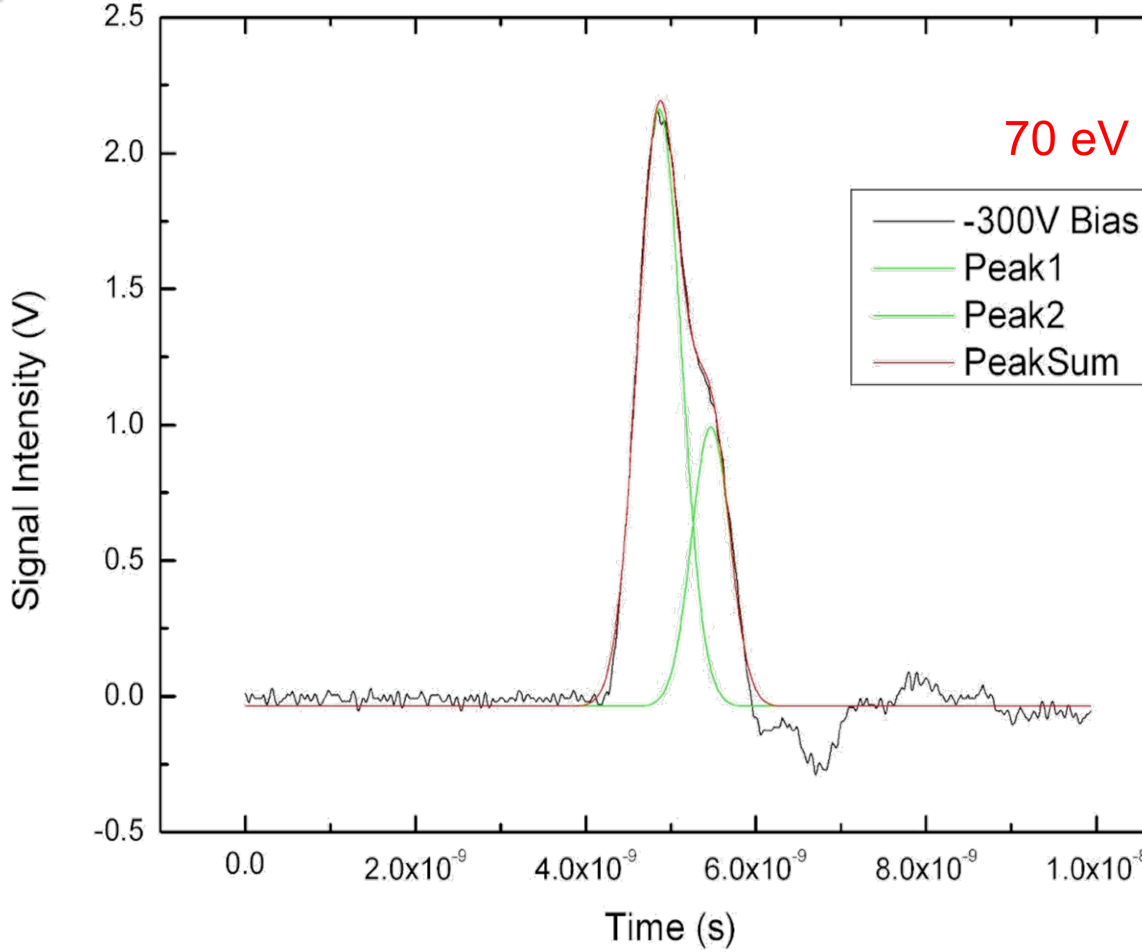


ΔT = 864 ns
Amplitude (mV)
0.060
0.055
0.050
0.045
0.040
0.035
0.030
0.025
0.020
-0.500
-0.250
0.000
0.250
0.500
0.750
1.000
1.250
1.500
1.750
2.000
Time (us)

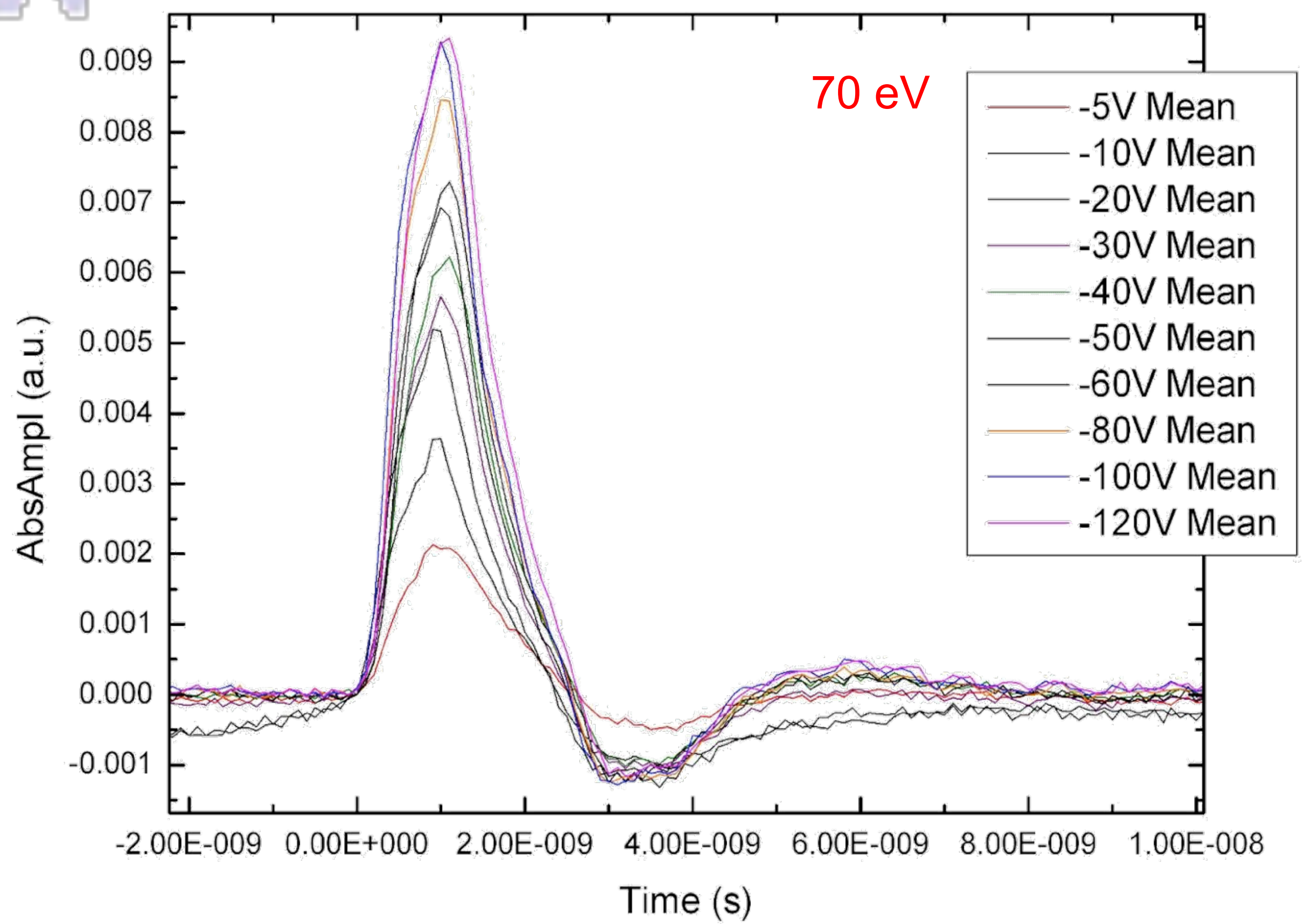
SCD/Cr-Au E6

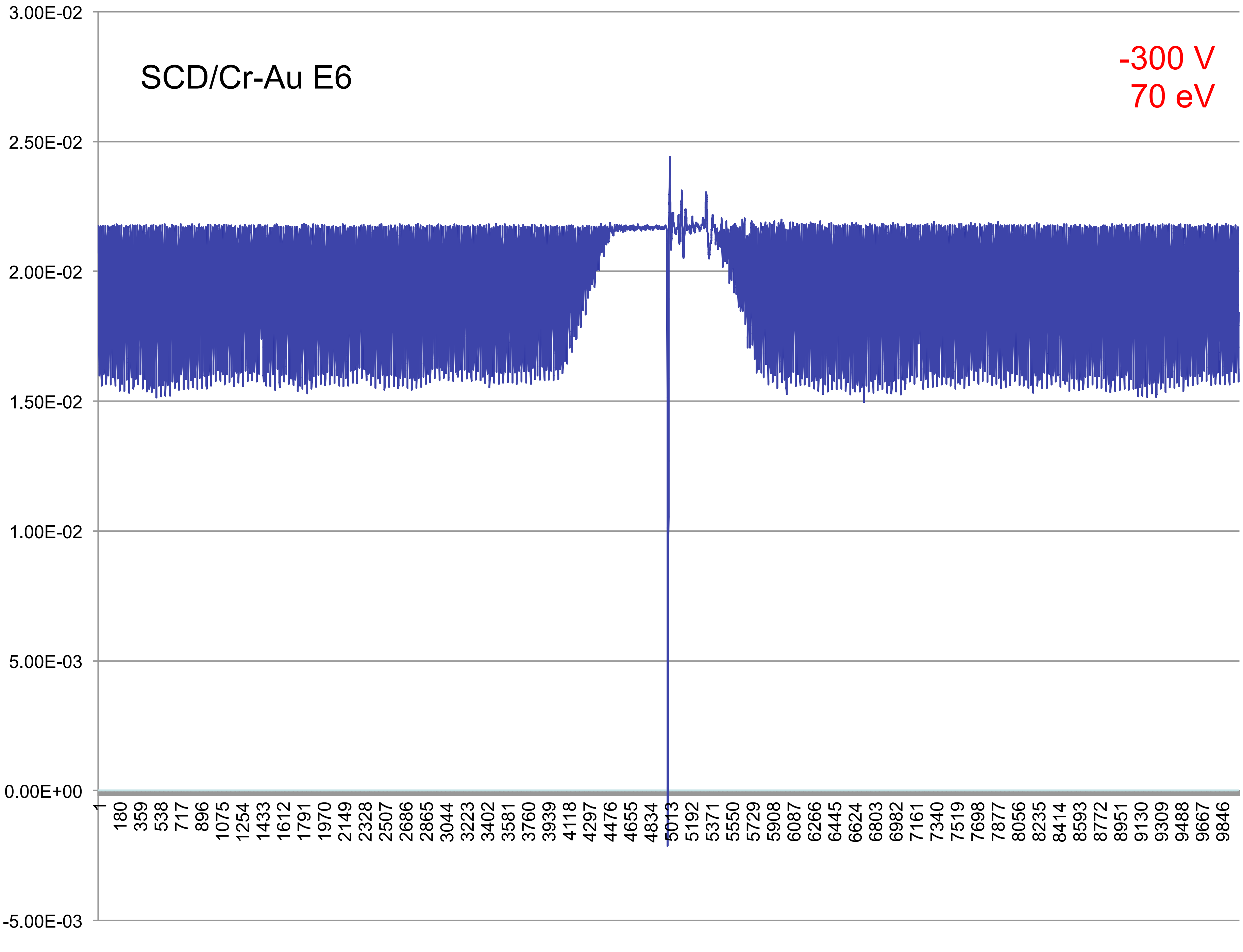


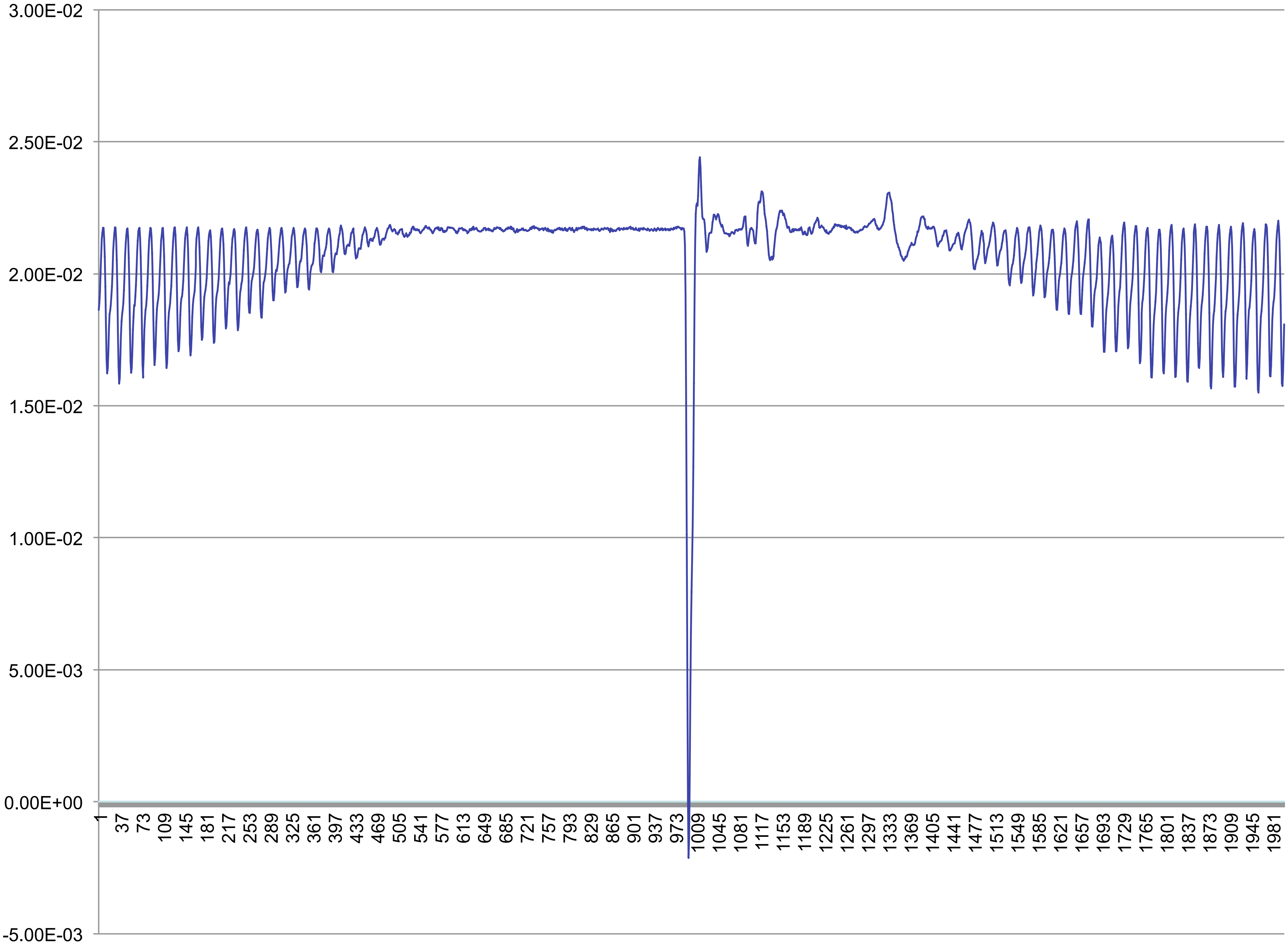
-300V Bias
-200V Bias
-100V Bias
70 eV
Signal Intensity (V)
Time (s)
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
0.0
2.0x10^-9
4.0x10^-9
6.0x10^-9
8.0x10^-9
1.0x10^-8

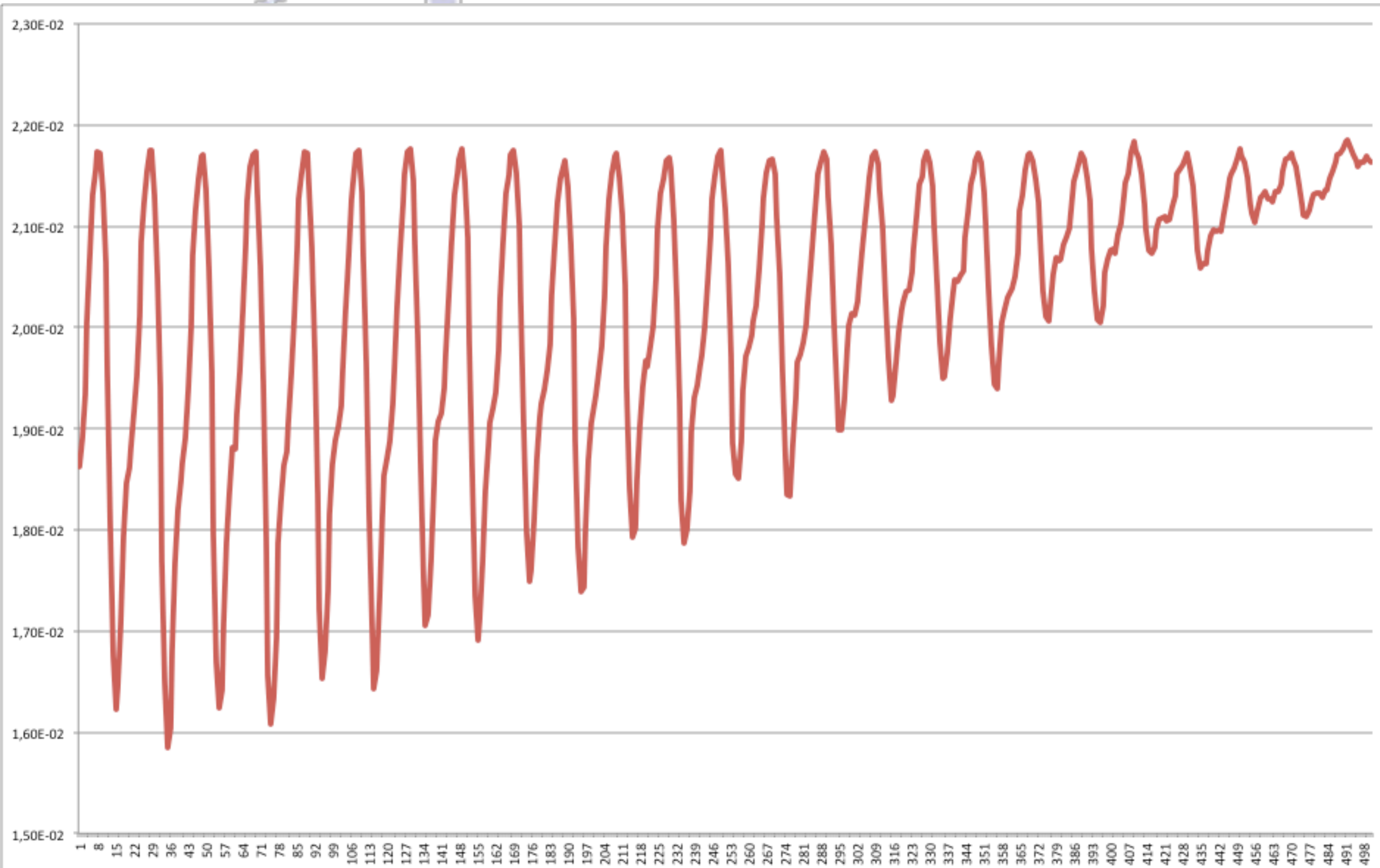

70 eV
-300V Bias
Peak1
Peak2
PeakSum
Signal Intensity (V)
Time (s)
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
0.0
2.0x10^-9
4.0x10^-9
6.0x10^-9
8.0x10^-9
1.0x10^-8

SCD/Al interdigitated UTOV

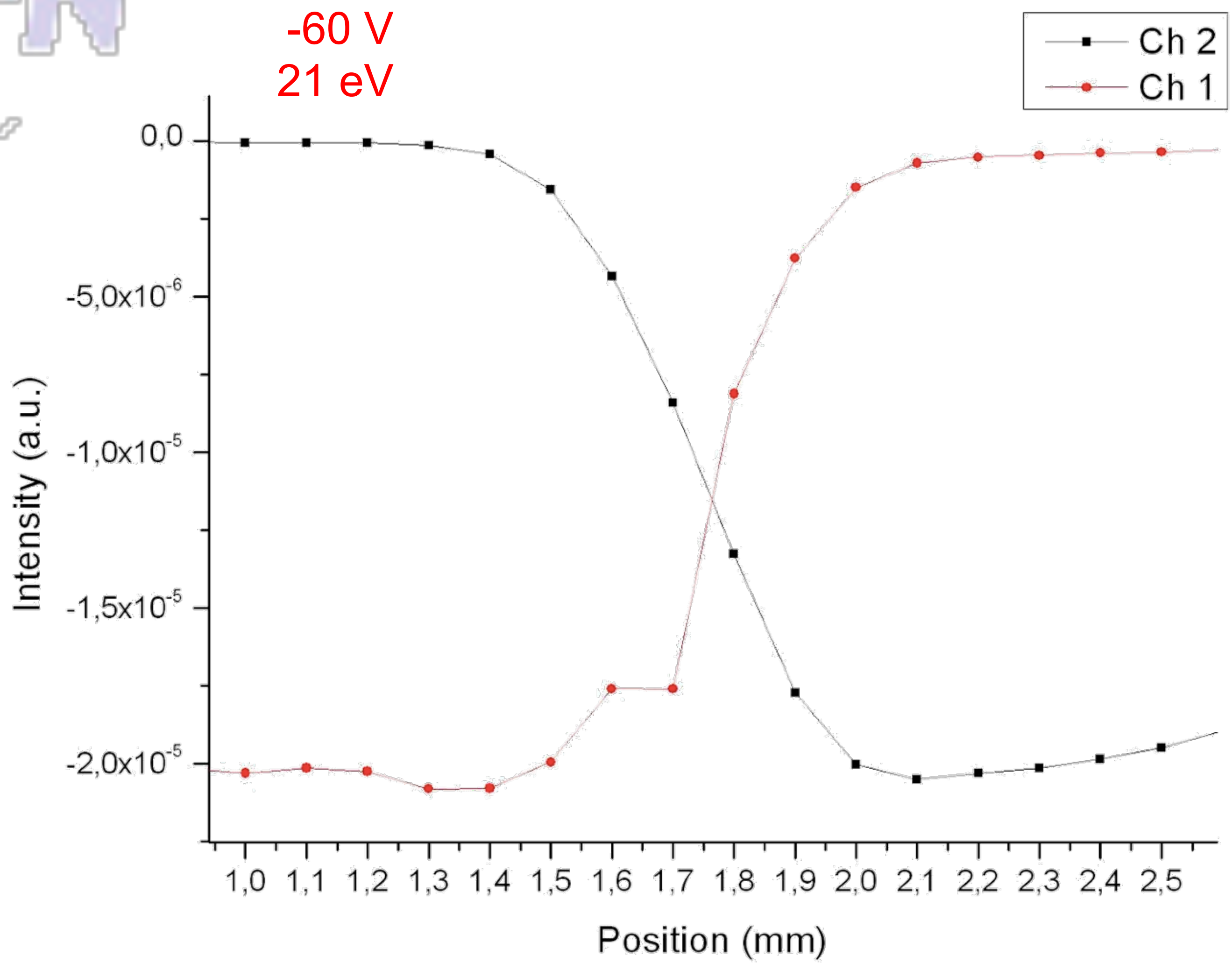



SCD/Cr-Au E6
-300 V
70 eV
3.00E-02
2.50E-02
2.00E-02
1.50E-02
1.00E-02
5.00E-03
0.00E+00
-5.00E-03
1
180
359
538
717
896
1075
1254
1433
1612
1791
1970
2149
2328
2507
2686
2865
3044
3223
3402
3581
3760
3939
4118
4297
4476
4655
4834
5013
5192
5371
5550
5729
5908
6087
6266
6445
6624
6803
6982
7161
7340
7519
7698
7877
8056
8235
8414
8593
8772
8951
9130
9309
9488
9667
9846

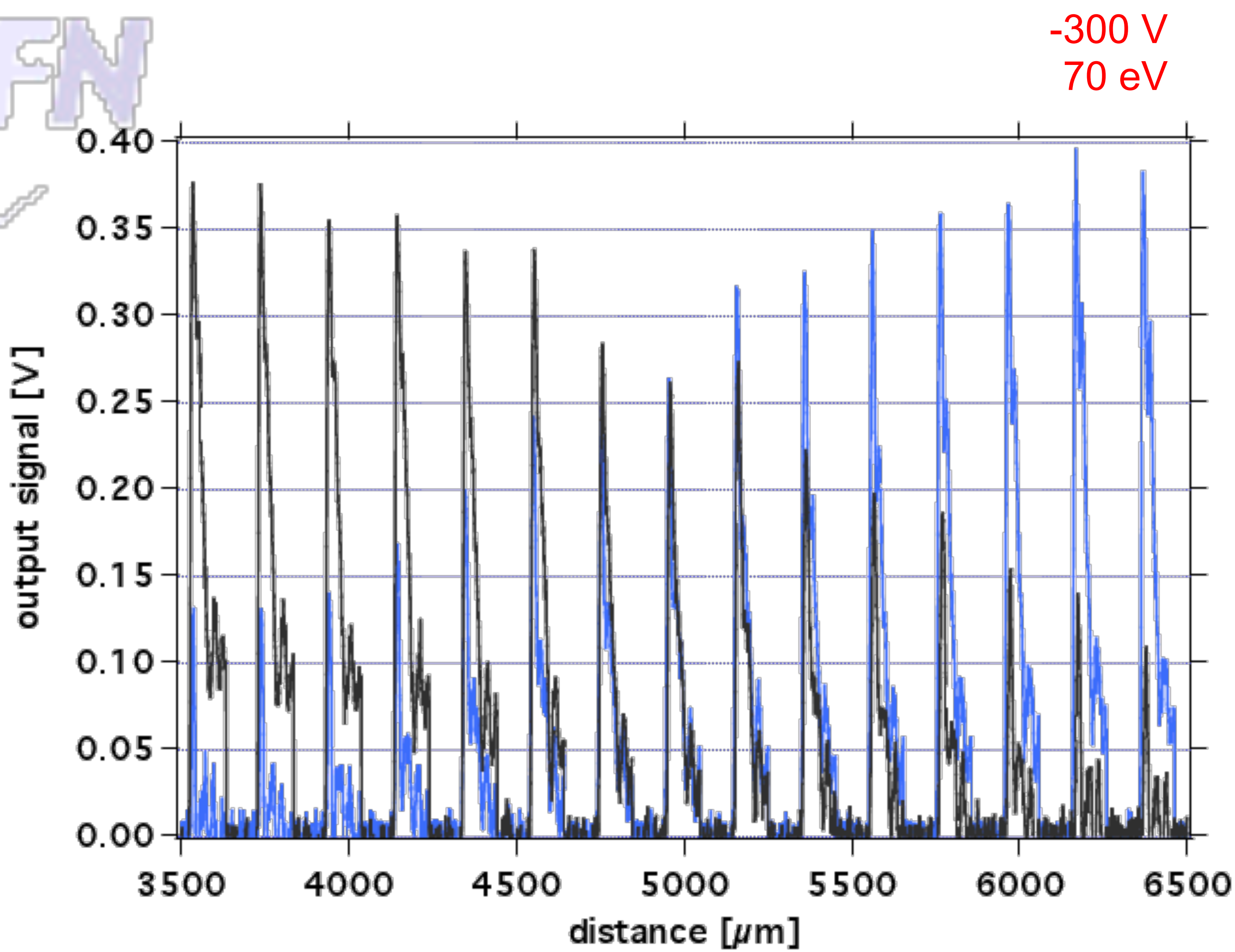

3.00E-02
2.50E-02
2.00E-02
1.50E-02
1.00E-02
5.00E-03
0.00E+00
-5.00E-03
1
37
73
109
145
181
217
253
289
325
361
397
433
469
505
541
577
613
649
685
721
757
793
829
865
901
937
973
1009
1045
1081
1117
1153
1189
1225
1261
1297
1333
1369
1405
1441
1477
1513
1549
1585
1621
1657
1693
1729
1765
1801
1837
1873
1909
1945
1981



2,30E-02
2,20E-02
2,10E-02
2,00E-02
1,90E-02
1,80E-02
1,70E-02
1,60E-02
1,50E-02
1 8 15 22 29 36 43 50 57 64 71 78 85 92 99 106 113 120 127 134 141 148 155 162 169 176 183 190 197 204 211 218 225 232 239 246 253 260 267 274 281 288 295 302 309 316 323 330 337 344 351 358 365 372 379 386 393 400 407 414 421 428 435 442 449 456 463 470 477 484 491 498



-60 V
21 eV
Ch 2
Ch 1
0,0
-5,0x10^-6
-1,0x10^-5
-1,5x10^-5
-2,0x10^-5
Intensity (a.u.)
1,0 1,1 1,2 1,3 1,4 1,5 1,6 1,7 1,8 1,9 2,0 2,1 2,2 2,3 2,4 2,5
Position (mm)


-300 V
70 eV
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
output signal [V]
3500
4000
4500
5000
5500
6000
6500
distance [μm]

Exo-biosphere evolution and biosignature characterization by FT-IR spectroscopy

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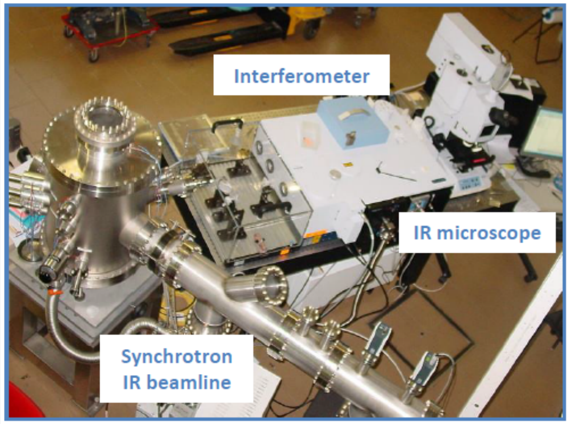
[1]INFN-Laboratori Nazionali di Frascati
[2]Università degli studi di Firenze
[3]Università degli studi di Roma 'La Sapienza'

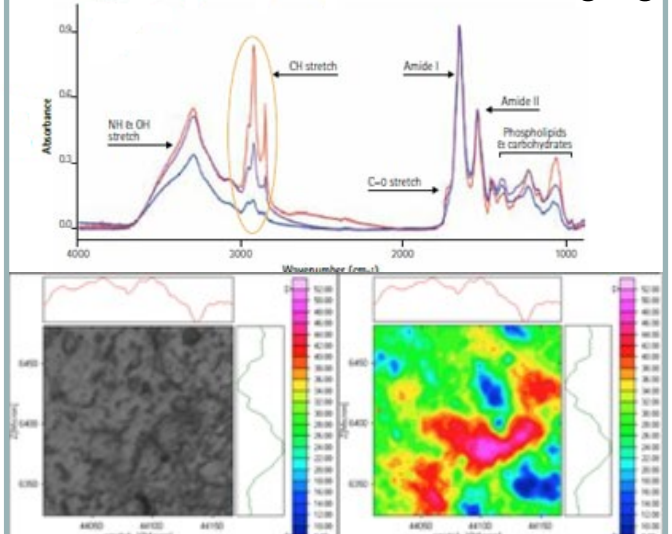
INFN DaΦne-Ligh synchrotron facility

A synchrotron facility operating with syncrotron and standard sources in the Infrared and UV-VIS energy range is open to external users.

Sinbad IR beamline
(1 mm – 0.5μm)

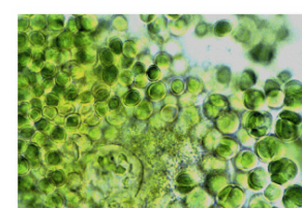


FPA detector for chemical imaging



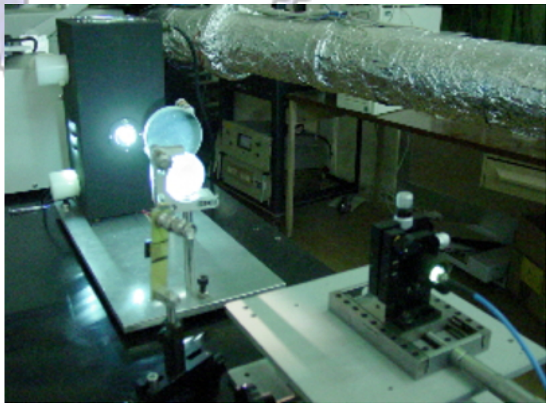
Long path gas cell

- Extended IR range (from Far-IR to NIR-VIS)
- Chemical microimaging of materials
- High temperature (1200°C) / high pressure (20 GPa) setup
- Real time study of photoageing processes
- Exo-biosphere evolution and biosignature characterization

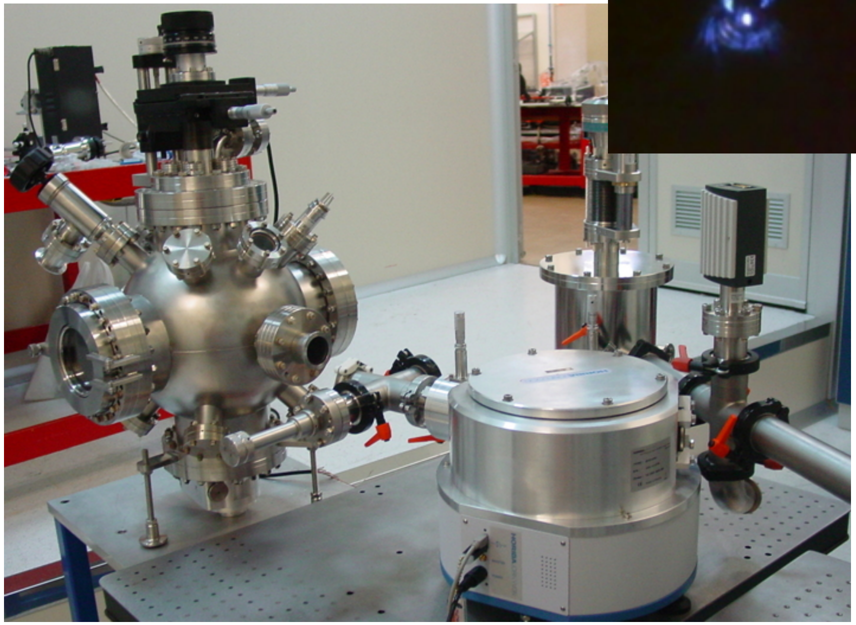


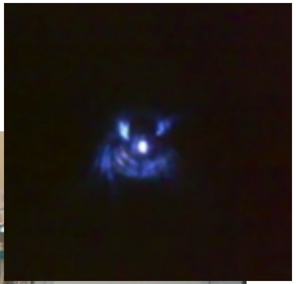
UV-VIS new setup: first light

First light on 02.02.2011. The optical design of the branch line was revised to improve the expected performance of the whole system. The previous design was based on a focusing optical system producing 1 mm spot at 2 m distance from the last folding mirror at the entrance mirror camera. To improve aperture matching – thus spectral resolution and beam intensity – with the monochromators, the design was changed in a collimated beam from the folding mirror. The collimated beam is focused with the proper aperture at the entrance slit of each of the two monochromators and of the optical fiber feeding the white beam channel. A 35 mm collimated beam is now available.



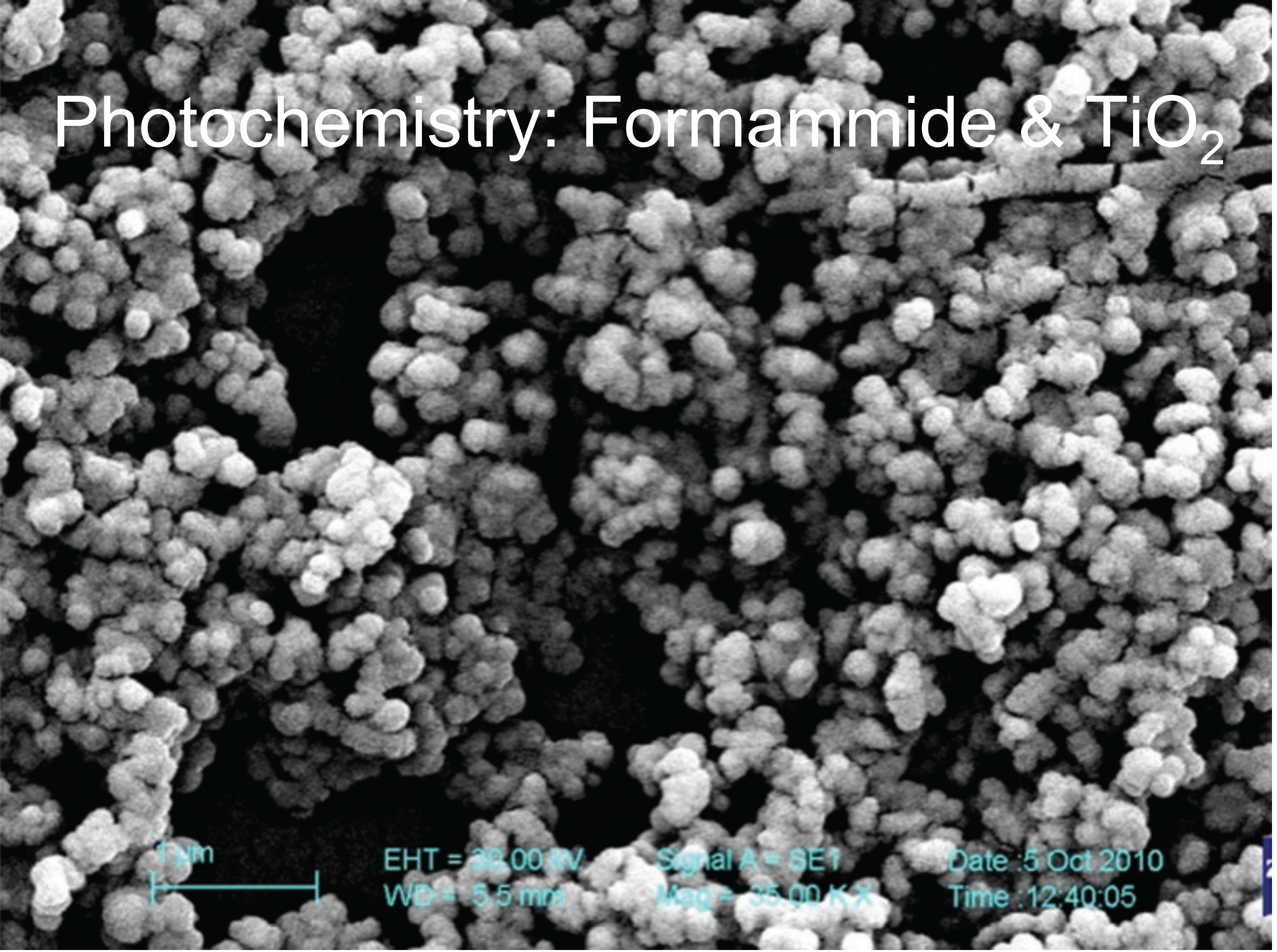
UV radiation transferred through solarized fiber optics





Instrumentation has been upgraded with a new VUV monochromator (UVXL200 by Jobin Yvon) operating in the 120-250 nm spectral range. It will be put on the SR beam line after focusing the collimated beam on the entrance slit with the appropriate aperture. The previous monochromator will be used coupled to a high power Deuterium lamp. This solution will improve the performance of the VUV SR channel and will offer the opportunity to double the VUV light sources available for experiments, such as UV irradiation, UV ageing, photobiology, etc.

Photochemistry: Formammide & TiO_2



Products

λ=(387.5 ± 2.14 nm)

TABLE 2. YIELD OF BIOGENIC CARBOXYLIC ACIDS 5–12 IN THE PRESENCE OF LARGE (ENTRIES 1–8) AND SMALL (ENTRIES 9–16) ANATASE GRAINS

Entry	*Product*	*Yield*[a]
1	Glycolic acid **5**	2.2
2	Lactic acid **6**	8.0
3	Pyruvic acid **7**	6.1
4	Succinic acid **8**	0.2
5	Malic acid **9**	0.5
6	Oxaloacetic acid **10**	n.d.
7	α-Ketoglutaric acid **11**	6.8
8	Fumaric acid **12**	0.05
9[b]	Glycolic acid **5**	2.5
10[b]	Lactic acid **6**	8.3
11[b]	Pyruvic acid **7**	6.2
12[b]	Succinic acid **8**	0.1
13[b]	Malic acid **9**	0.8
14[b]	Oxaloacetic acid **10**	5.1
15[b]	α-Ketoglutaric acid **11**	6.9
16[b]	Fumaric acid **12**	0.1

[a]Product yield is expressed as milligrams of product with respect to initial amount in grams of formamide.
[b]Data obtained with TiO_2 anatase ground in an agate mortar.
n.d., not determined.

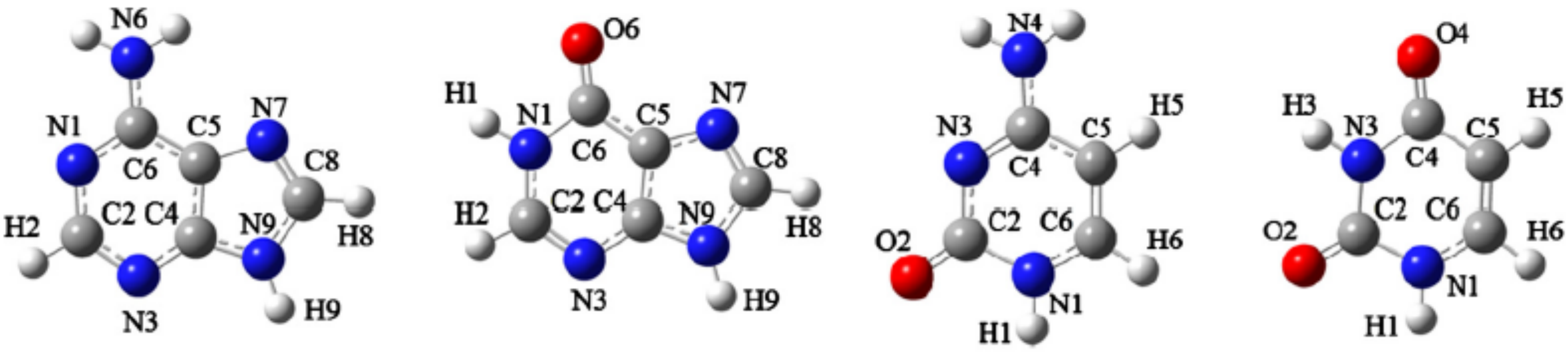
TABLE 3. YIELD OF CARBOXYLIC ACIDS 13–19 AND HETEROCYCLES 20–21 IN THE PRESENCE OF LARGE (ENTRIES 1–9) AND SMALL (ENTRIES 9–18) ANATASE GRAINS

Entry	*Product*	*Yield*[a]
1	Ethanimidic acid **13**	2.42
2	Propanoic acid **14**	2.11
3	2,3-Dihydroxypropanoic acid **15**	0.41
4	2,3-Dihydroxybutanoic acid **16**	n.d.
5	2,4-Dihydroxybutanoic acid **17**	n.d.
6	Oxalic acid **18**	1.54
7	Malonic acid **19**	2.46
8	3-Hydroxypyridine **20**	0.02
9	4(3*H*)-Pyrimidinone **21**	0.06
10[b]	Ethanamidic acid **13**	n.d.
11[b]	Propanoic acid **14**	n.d.
12[b]	2,3-Dihydroxypropanoic acid **15**	1.10
13[b]	2,3-Dihydroxybutanoic acid **16**	0.64
14[b]	3,4-Dihydroxybutanoic acid **17**	0.35
15[b]	Oxalic acid **18**	n.d
16[b]	Malonic acid **19**	n.d.
17[b]	3-Hydroxypyridine **20**	0.07
18[b]	4(3*H*)-Pyrimidinone **21**	0.10

[a]Product yield is expressed as milligrams of product with respect to initial amount in grams of formamide.
[b]Data obtained with TiO_2 anatase ground in an agate mortar.
n.d., not determined.

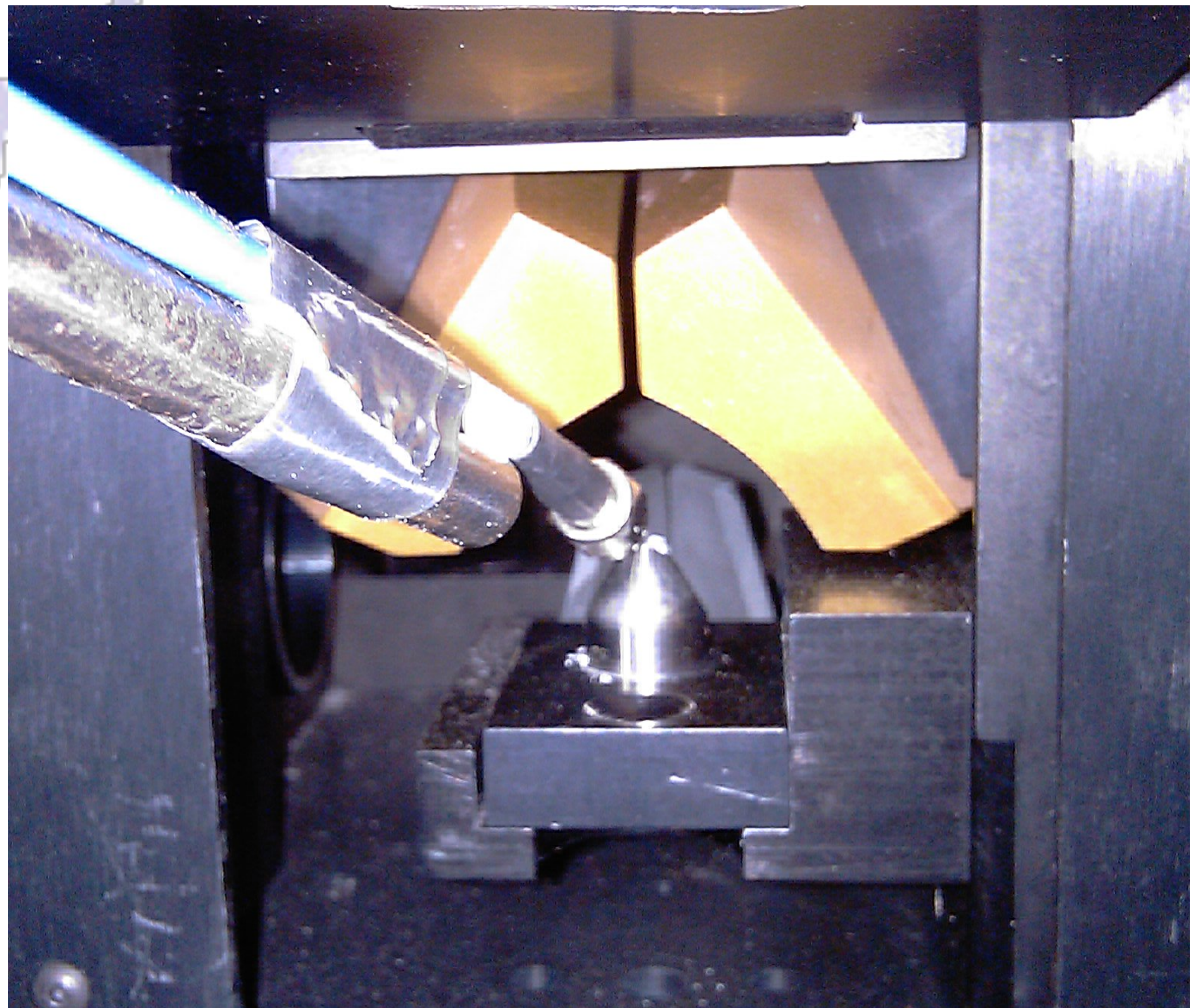
UV irradiation of aminoacids

Analysis: FTIR spectroscopy



Adenine **Hypoxanthine** **Cytosine** **Uracil**

Exp Apparatus



FTIR spectra

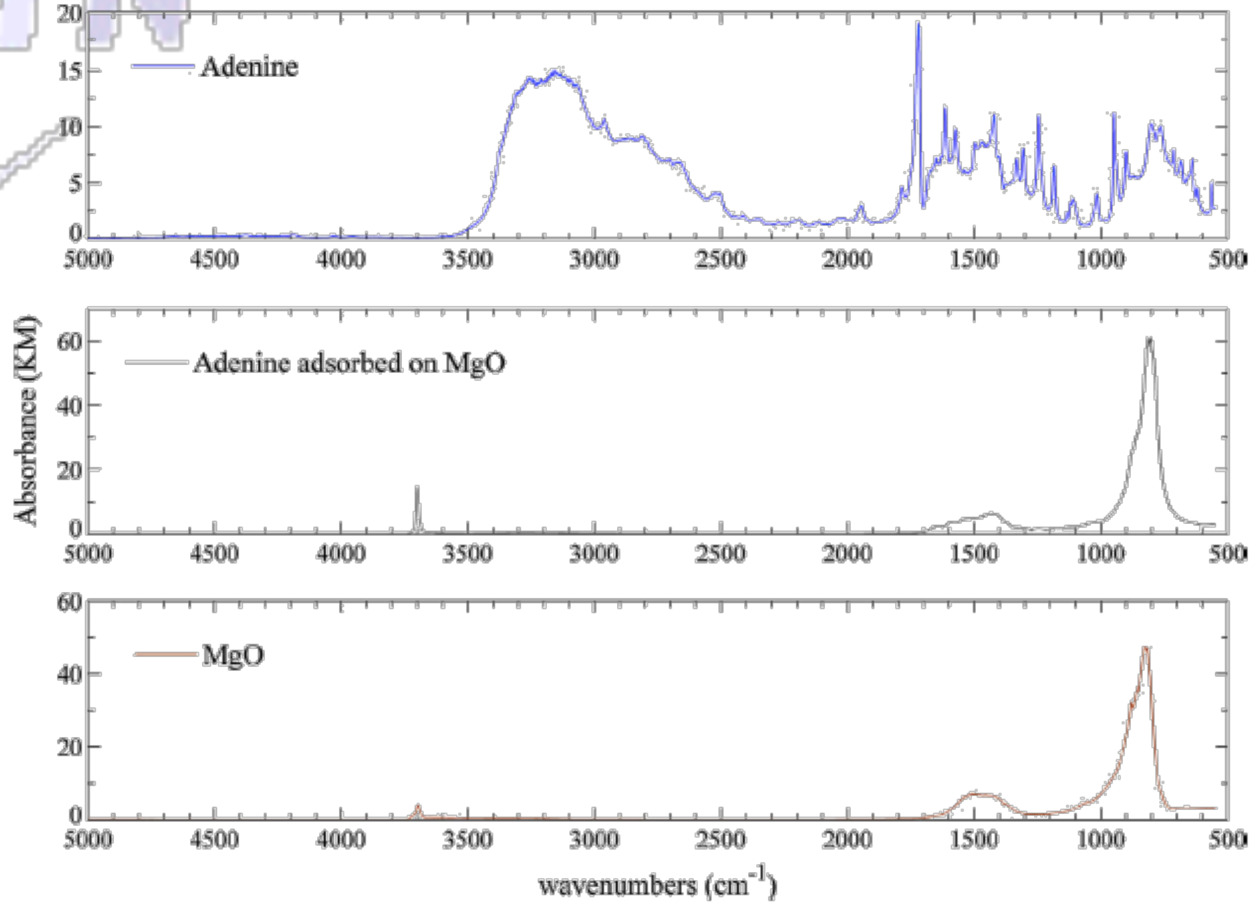


Fig. 2. IR spectra of pure adenine, adenine adsorbed on MgO and pure MgO, represented in Kubelka–Munk units (KM) *vs* wavenumbers (cm^{-1}).

FTIR spectra

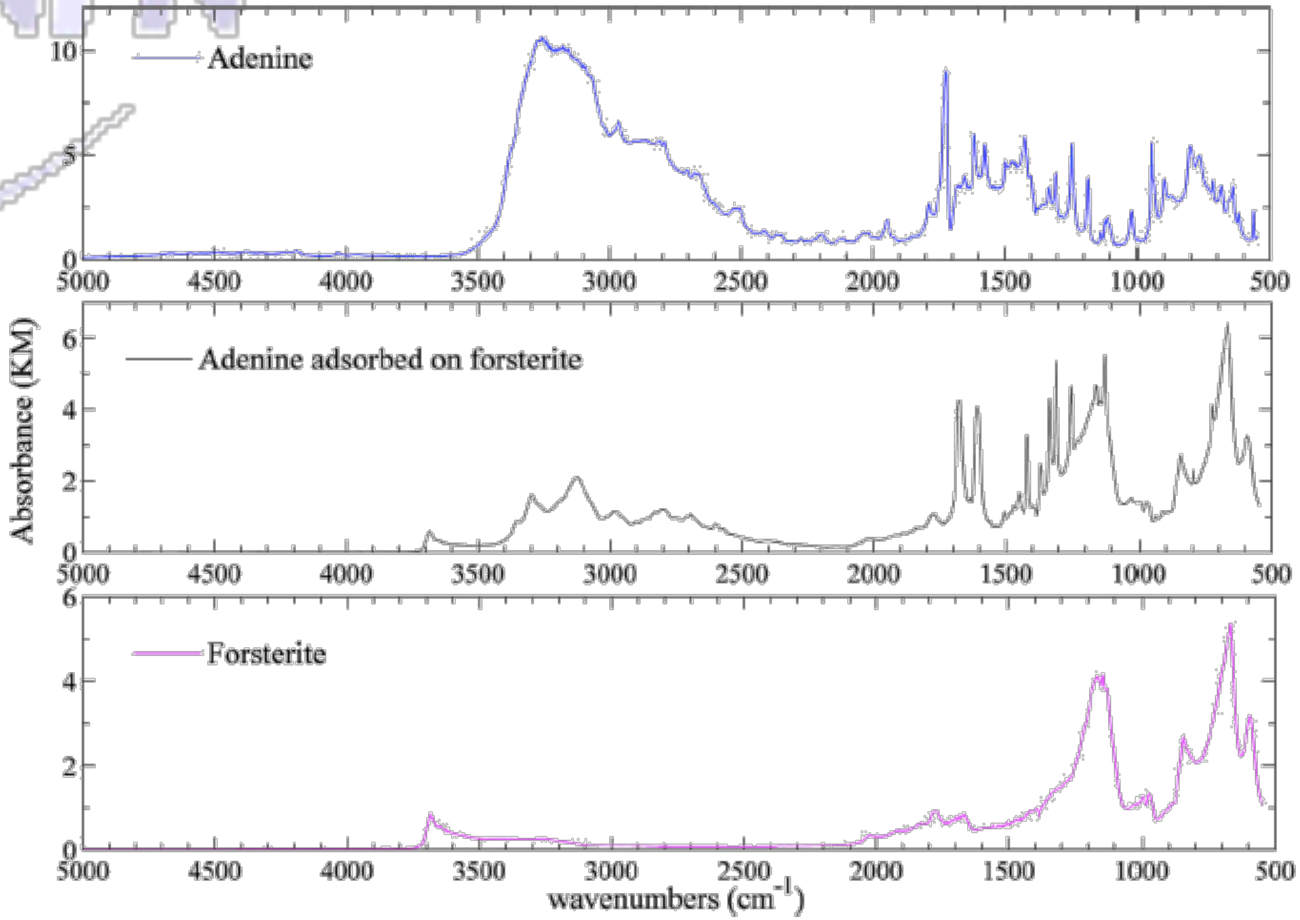
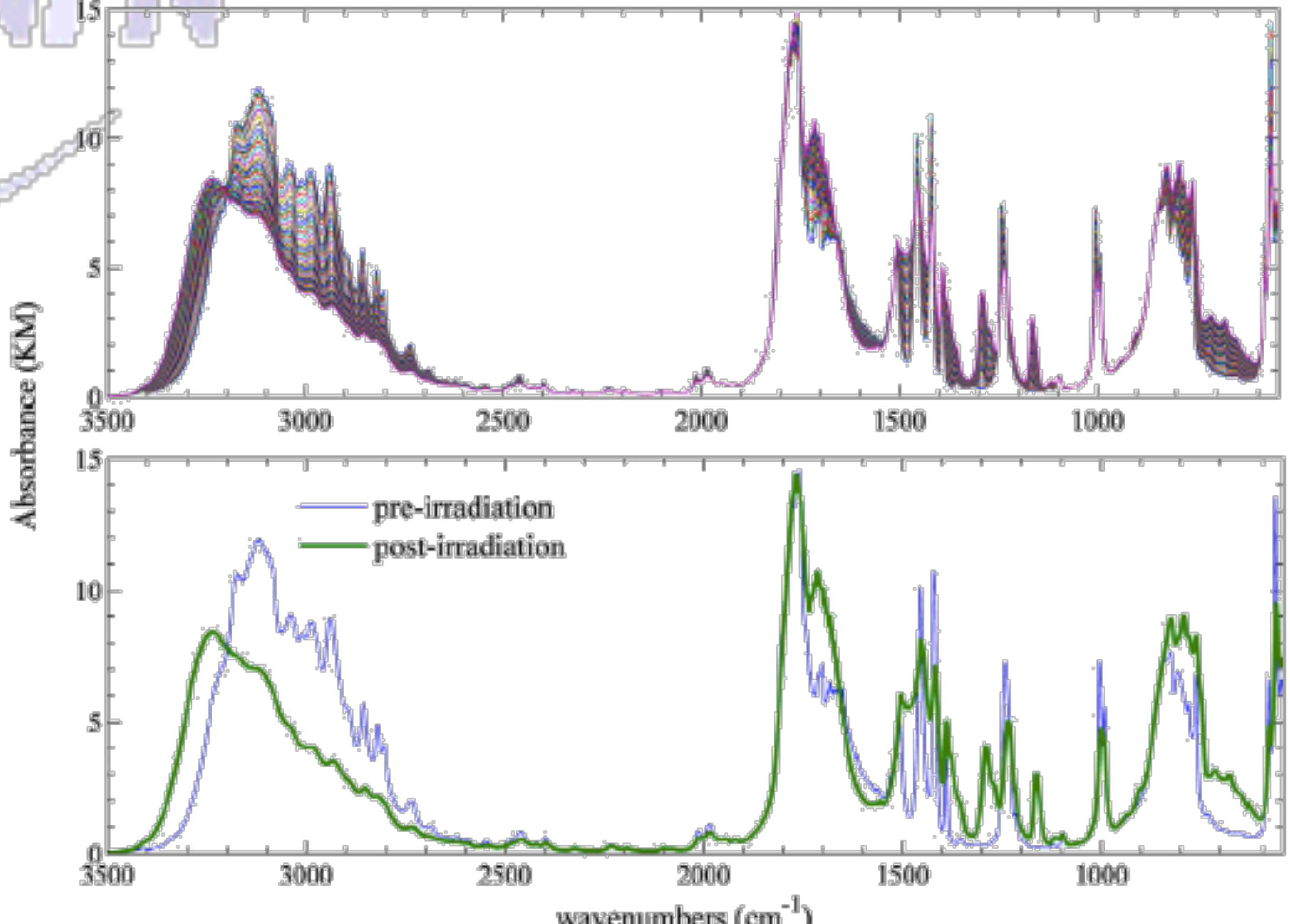


Fig. 3. IR spectra of pure adenine, adenine adsorbed on forsterite and pure forsterite, represented in Kubelka–Munk units (KM) *vs* wavenumbers (cm^{-1}).

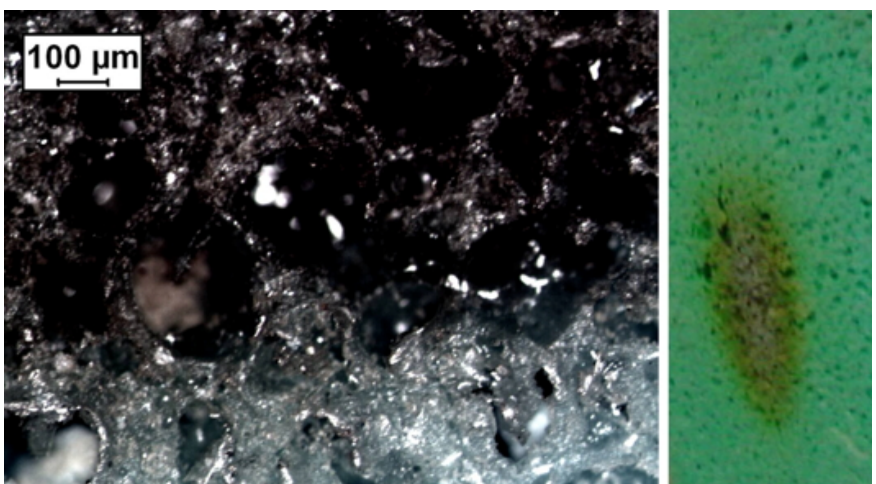
FTIR spectra



Ageing of materials and coatings

Ageing of FOAM

Irradiated FOAM sample after 8 hours at the focus (right) as it appears at a zoomed observation (left)



FOAM is a memory form material that has been developed for space application. Memory form materials are used to recover the original form of the material after being properly modified for the application; so, it can be stretched, pressed, turned and it can recover the original form by applying thermal energy warming it at around 100°C. UV ageing is one of the main issues, because there is a lot of UV radiation in outer space and this material might undergo degradation after prolonged exposure to UV radiation.

Samples of this material were irradiated for several hours (from 1 up to 30 hours) with a 10^{13} ph/s white beam. The samples were put firstly on the focus and then on the defocused beam to avoid any effect of thermal degradation. After irradiation the samples show brownish regions corresponding to the beam. Irradiated materials were characterized by the Differential Scanning Calorimetry (DSC) technique that shows no variation highlighting that UV ageing effects had no effects on in the amount of heat required to increase the sample temperature . To assess this result the sample was irradiated with IR radiation to have a direct comparison between photo ageing and thermal ageing.

FEL VUV
Sorgente

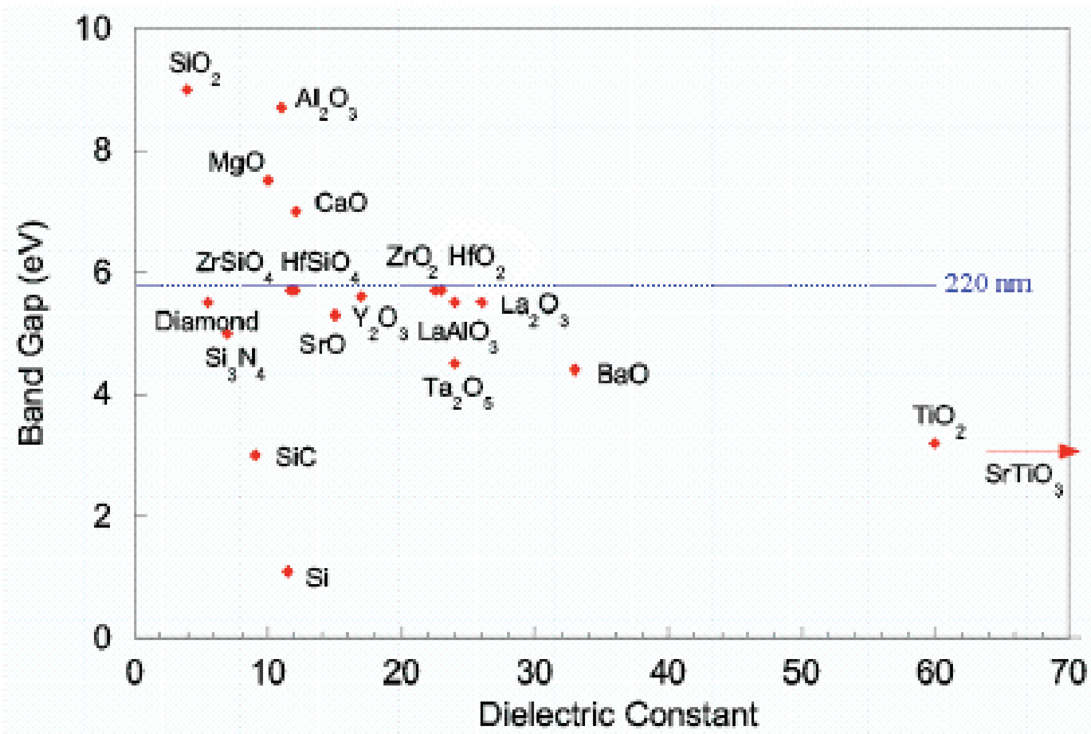
- seeding could allow to work with high harmonics in the UV domain: 250-90(~ 40!) nm @ 155 MeV
- repetition rate: 1-10 Hz
- radiation spectrum slightly tunable
- higher harmonics linearly polarized sources of high temporal and spatial coherence
- pulse duration: 100 fs

FEL VUV
Applicazioni

Raman & PL spectroscopy on isolated building blocks of nanostructured films

Raman spectroscopy is among most popular methods for characterization of nano-structured systems. The ability of the VUV-FEL to shift the wavelength of scattered light from visible into deep UV will allow to probe new electronic transitions well within the **7-10 eV** range for classes of cluster materials such as nano-carbons and potential gap dielectrics from metal oxides

band gap and dielectic constant of potential gate dielectrics



Raman Imaging…!

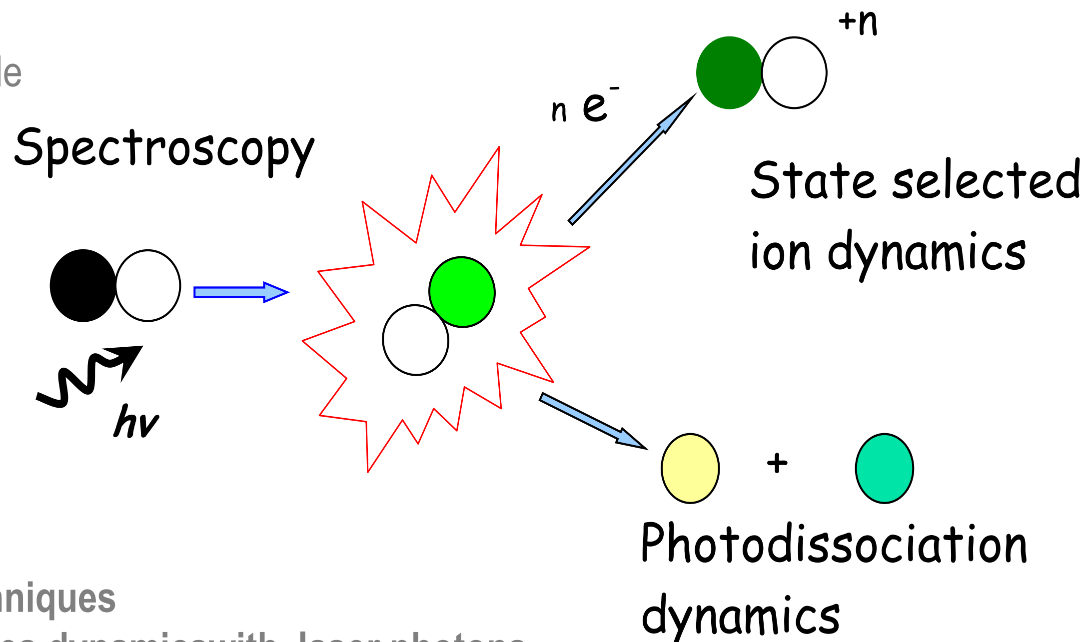
FEL & Atomic and Molecular Physics

SPECTROSCOPY OF "EXOTIC SPECIES"

High flux and Resolution allow thorough investigations of the electronic structure of low density matter:metastable and reactive species, i.e., high temperature species, atmospheric chemistry, combustion chemistry, isolated Molecules and Clusters in Supersonic Molecular Beam (condensation and nucleation studies, coupling to laser techniques for state selected excitation and photoemission studies)

MULTIPHOTON PROCESSES

Access to electronic states, transparent to single photon techniques ruled by dipole interaction



EXPERIMENTAL ADVANTAGES

Simple use of TOF and time-correlation techniques
"Pump & Probe" techniques for excited states dynamicswith laser photons

Direct measurement of lifetime; accurate analysis of intra- and inter-molecular energy transfer; interaction of photo-emitted electrons from gaseous samples with laser; electromagnetic field exploited at the same time as a diagnostic for FEL pulses ("side bands experiments") and for the investigation of photo-ionization dynamics

Electronic properties of biomolecules and their clusters

Solvent-free environment :

→ easier modeling of different intermolecular forces

→ results comparable with theoretical calculations

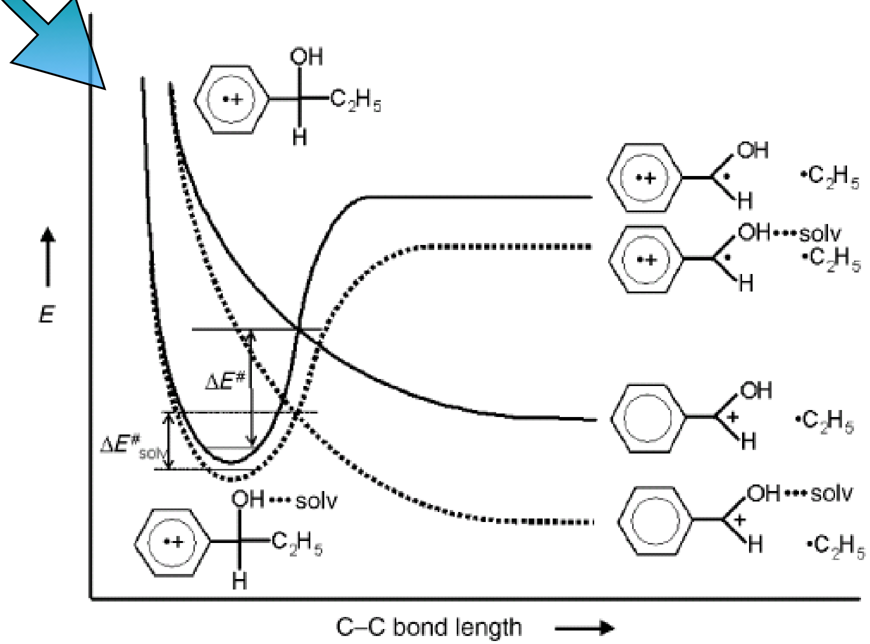
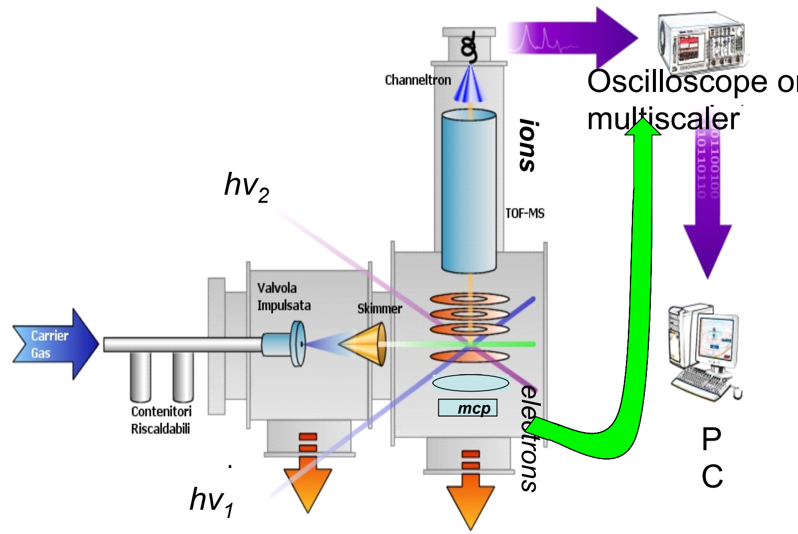
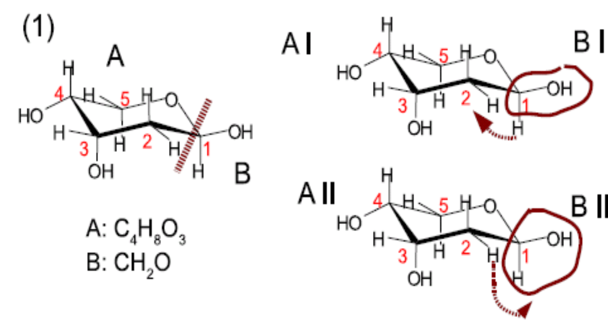


Figure 1. Pictorial crossing between the two lowest-energy electronic states of $[(BZC_2H_5)_R]^+$ (full lines) and $[(BZC_2H_5)_R{\cdot}solv]^+$ (broken lines).

TOF set-up @ CNR-IMIP & Unversity Tor Vergata





variable polarization and λ < 150 nm from SPARC will extend investigation to s-bonded systems like sugars and non aromatic aminoacids and implement valence photoemission techniques for the study of chiral recognition

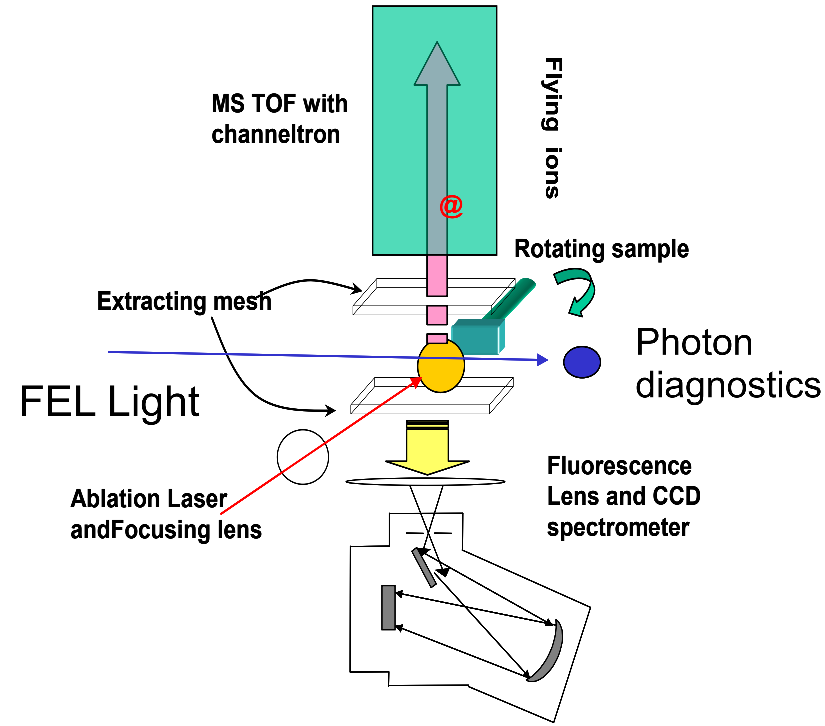
Surface modification and ablation studies

Stefano Orlando (CNR-IMIP, Rome) & Jesus Alvarez Ruiz (CSIC, Madrid)

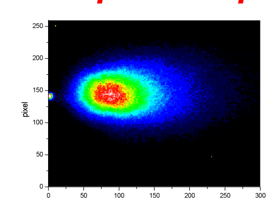
FEL VUV Applicazioni

Many important elementary processes such as electron/hole recombination, excitation relaxation, etc., often occur on a much shorter time scale and only a time resolved spectroscopy is able to elucidate the dynamics of charge and energy transfer processes. Ultra-short laser pulses limit the secondary ionization and photo-fragmentation, and exclude the laser/plume interaction. Therefore, only within such excitation regime, time- and space-resolved optical spectroscopy of the generated plasma provides a direct investigation of laser-target interaction and ultimately of particle emission.

Photoemission and diffraction studies of the ablated species condensed on a substrate as a function of the laser pulses will be used for the analysis of the ablation products and optimization of the process with a view to application to thin film deposition.



1.2 ps laser pulses



200 fs laser pulses