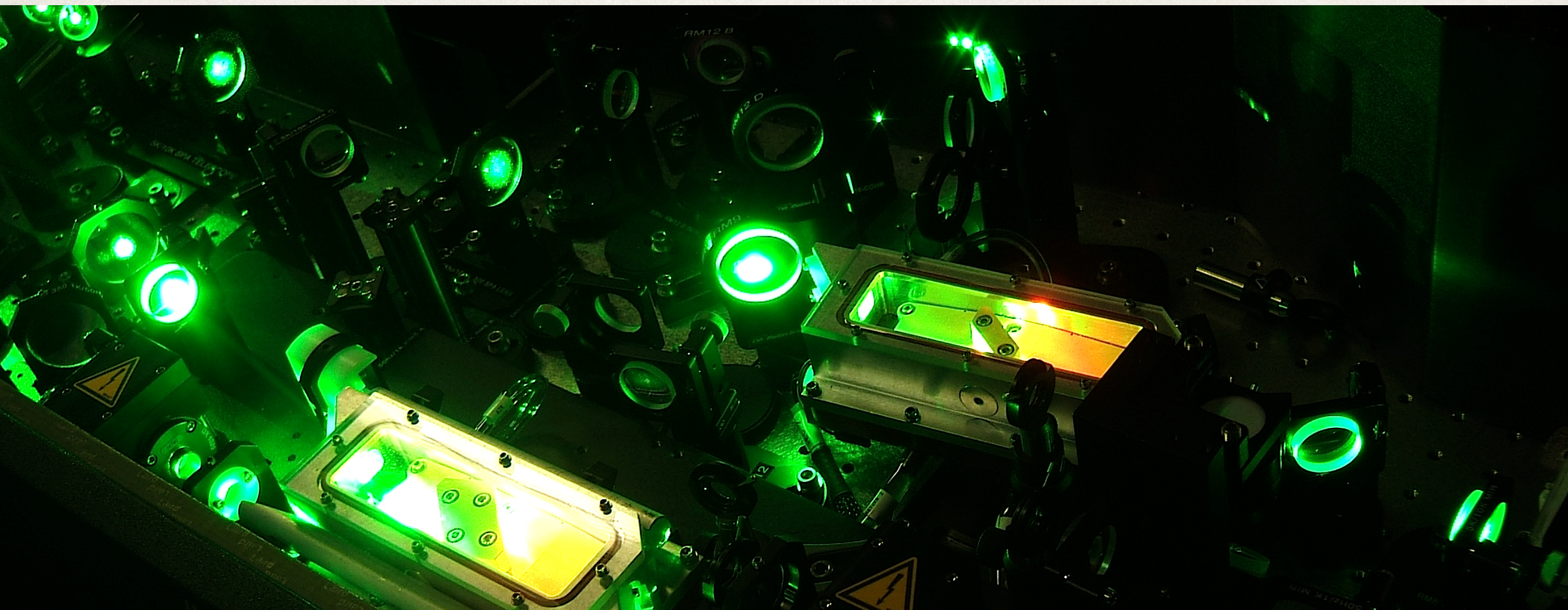




# The CITIUS light source

Barbara Ressel - Laboratory of Quantum Optics, Univ. Nova Gorica

---

*EUROREG WS ON PHOTOVOLTAICS, Ljubljana, Sept. 1<sup>st</sup> 2014*

# OUTLINE

---

- ❖ What is CITIUS
- ❖ The LASER and HHG source
- ❖ Time resolved spectroscopy
- ❖ Applications on solar cells investigations

# CITIUS

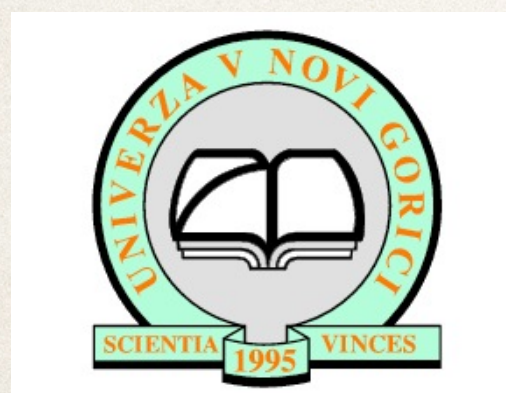


## Interregional Centre of Ultrafast Photonic Technology for Spectroscopies

Centro Interregionale di Tecnologie Ultraveloci per la Spettroscopia  
Medregijski center za ultrahitre fotonske tehnologije v spektroskopiji

funded by the Program for Cross-Border Italy-Slovenia Cooperation 2007-2013

<http://www.citius-lab.eu>



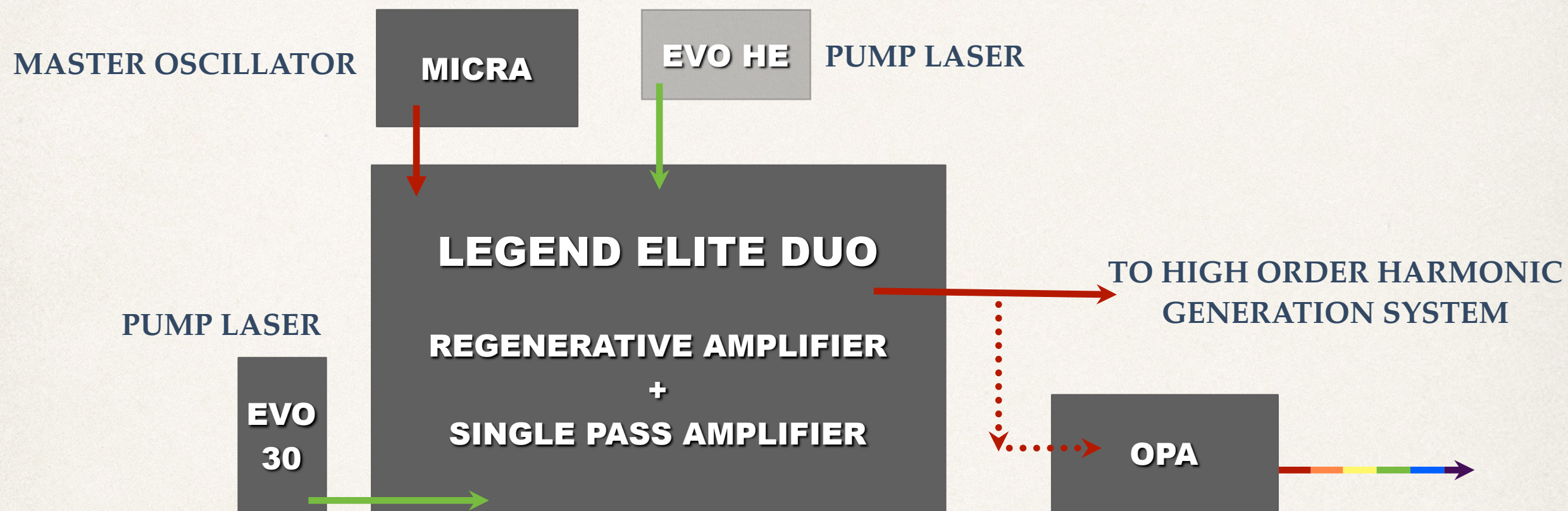
# LIGHT SOURCE PROPERTIES

---

- ❖ soft x-rays / EUV;
- ❖ monochromatic;
- ❖ tunable;
- ❖ short independent pulses (less than 100 femtosec) at high repetition rate;
- ❖ stable and reproducible.

ULTRAFAST LASER AND  
ITS HIGH ORDER HARMONICS

# THE LASER SOURCE



Commercial Ti:SA laser system, Coherent Inc.

wavelength  $\lambda = 800$  nm

FWHM 40 nm

time duration 40 fs

rep. rate (1-5) kHz

3 mJ per pulse

OPTICAL PARAMETRIC AMPLIFIER

tunable output wavelengths

240 nm - 2600 nm

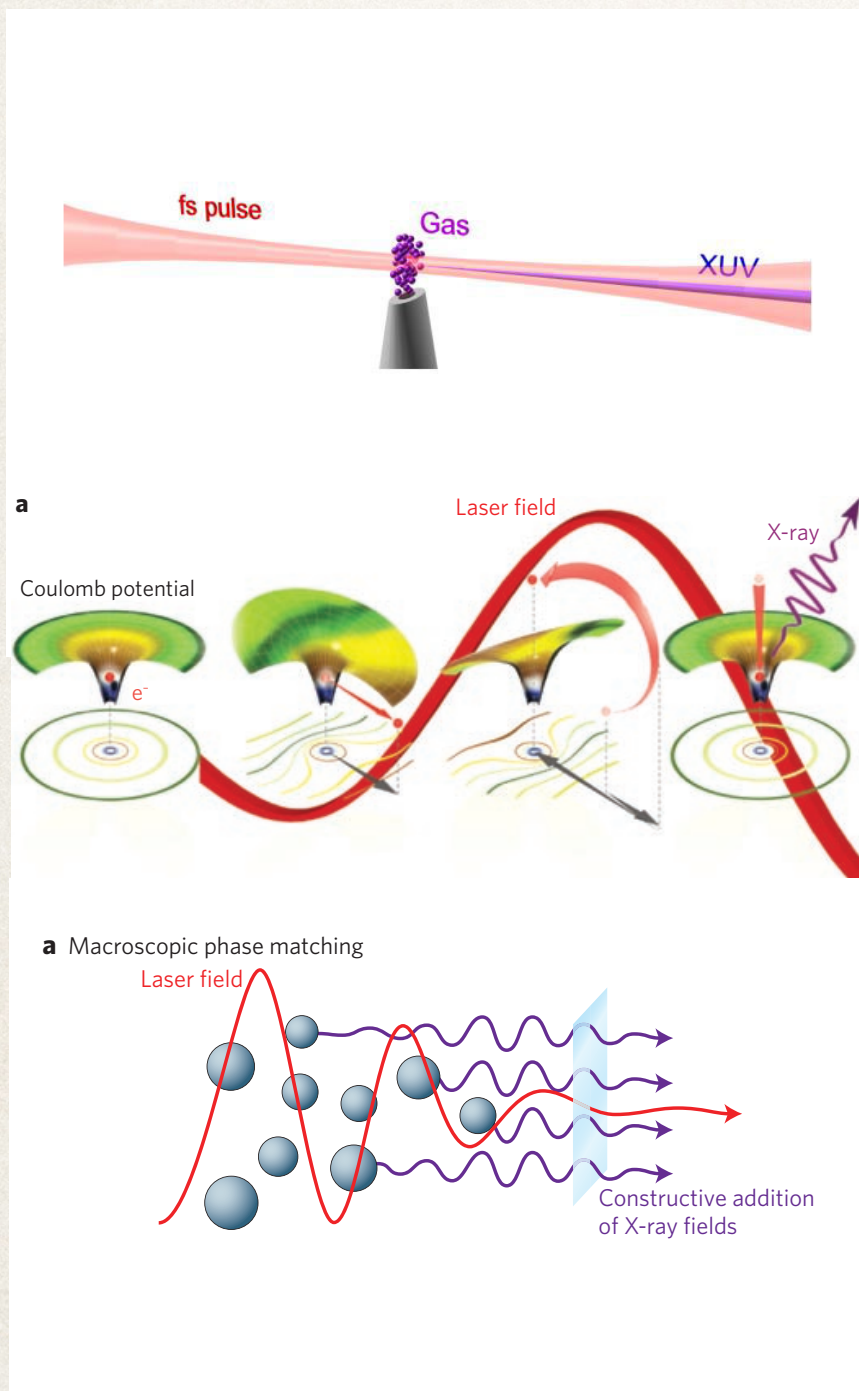
(more than 5 microJ / pulse)

# HHG generation process

An intense femtosecond driving laser (visible to IR) pulse intercepts a gas-jet (Ar, Ne, Kr,...)

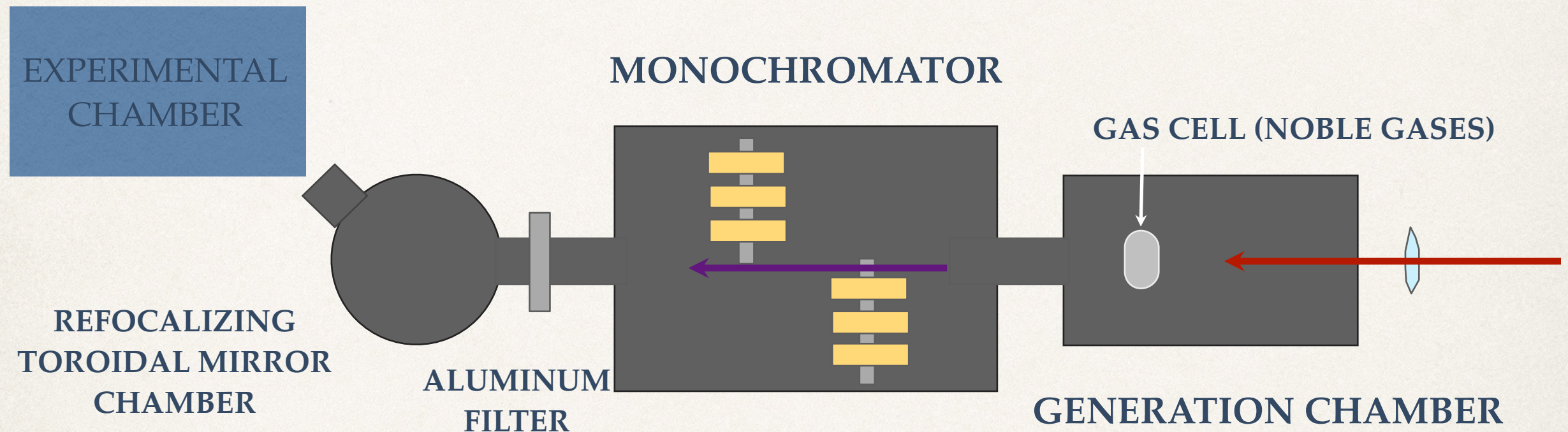
Electrons extracted from the atoms through tunnel ionization, gain energy in the (laser) electric field, and recombine with the parent atoms by emitting harmonics of the driving laser (XUV light or X-rays)

Efficient generation of harmonics is insured by proper phase-matching



T. Popmintchev, M.-C. Chen, P. Arpin, M. M. Murnane and H. C. Kapteyn, *Nat. Photonics* 4 (2010) 822  
T. Popmintchev *et al.*, *Science* 336 (2012) 1287

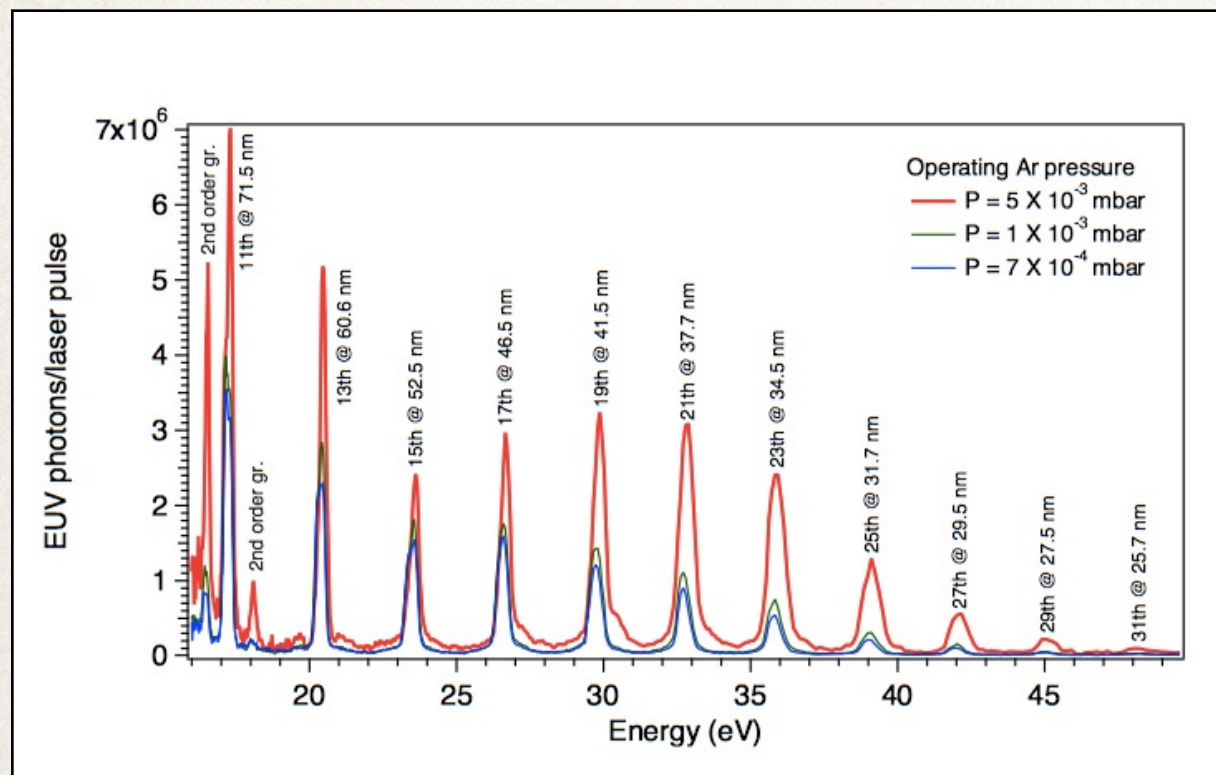
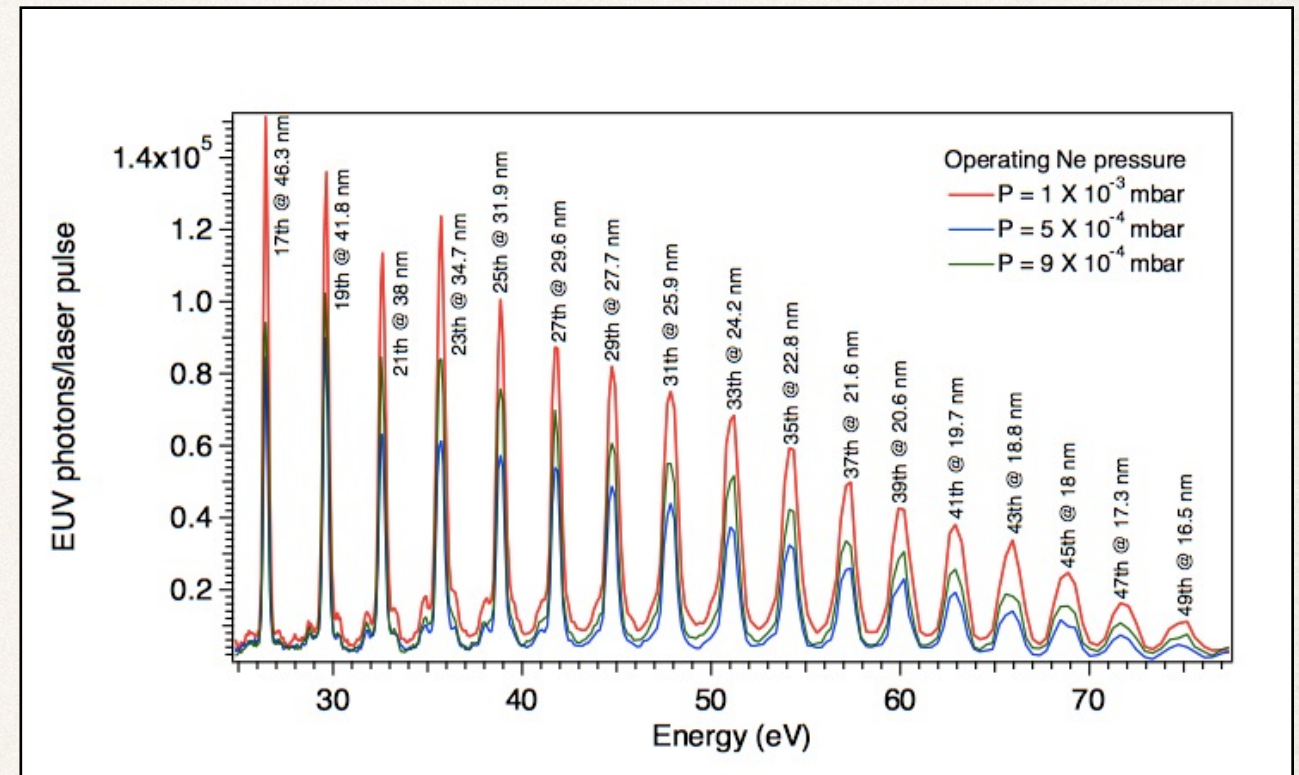
# The HHG beamline



2 possible configurations:

- “classical” geometry
- “off-plane” geometry  
(conical gratings)

# HHG PHOTONS



For the nature of the process, only odd harmonics  
of the fundamental laser frequency are produced

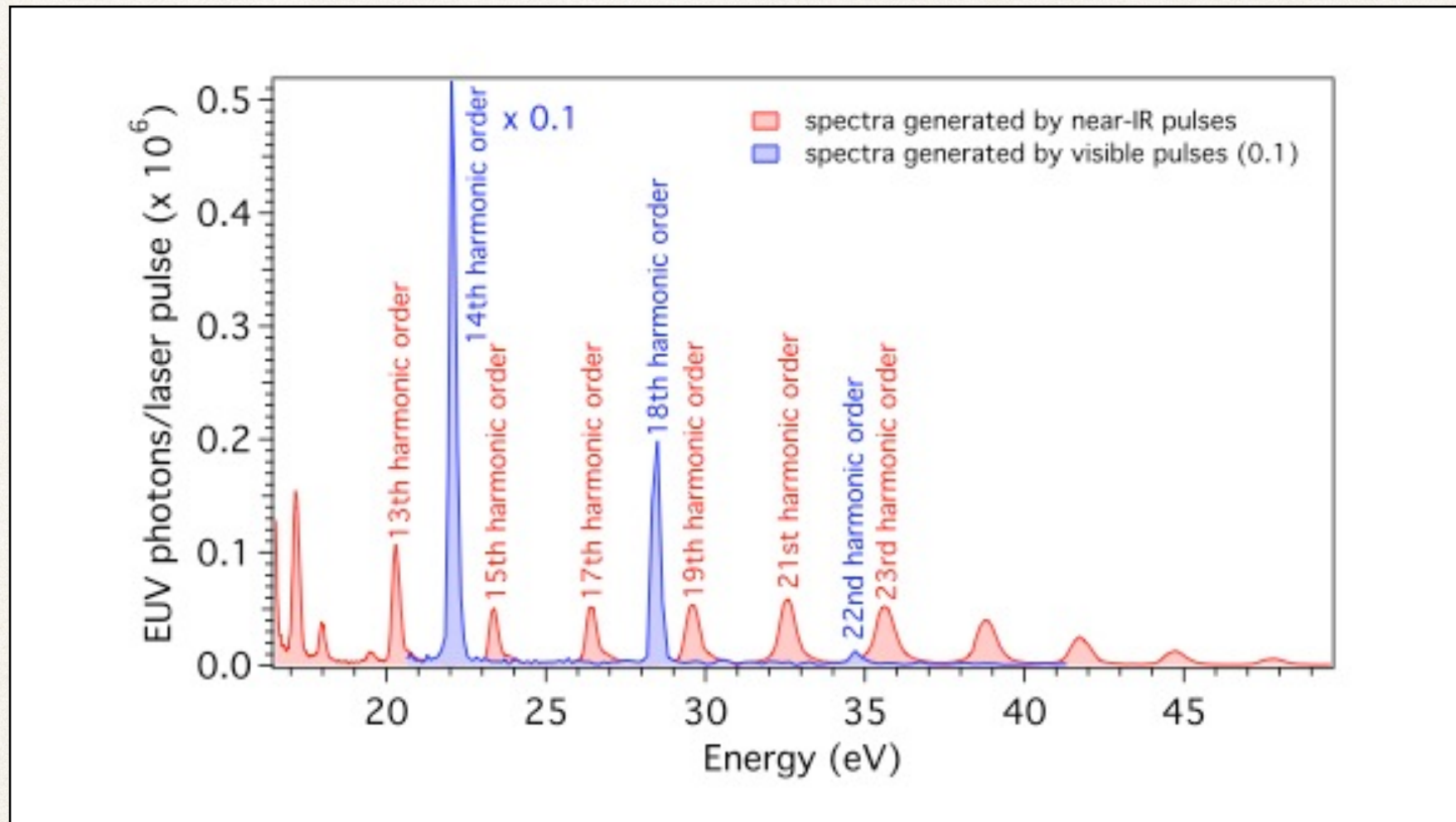
Photons energy range: 15 eV - 70 eV

Photon flux  $> 10^5$  ph/pulse

repetition rate 5 kHz, temporal duration  $< 40$  fs

Linear polarization as the driving laser

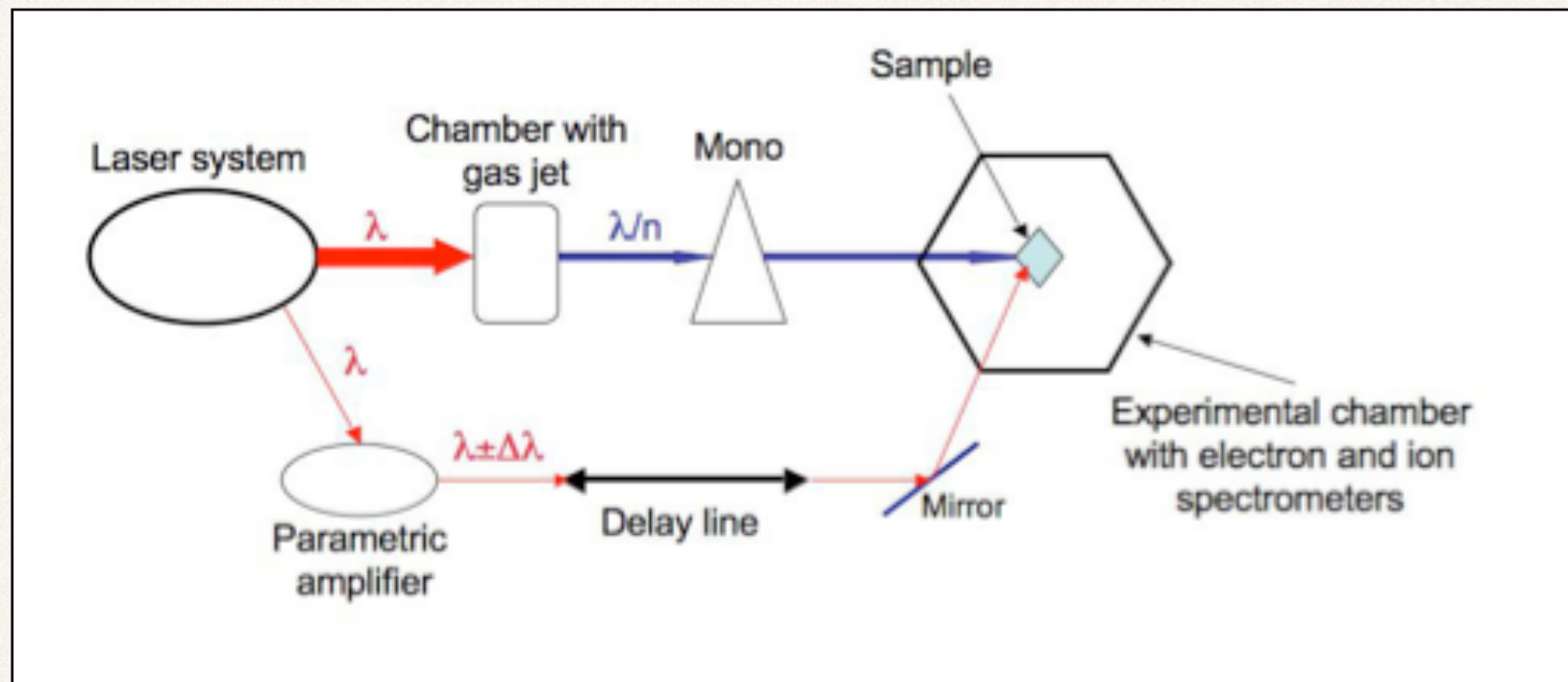
# HHG PHOTONS - $\lambda/2$



Using  $\lambda/2$  as driving laser field,  
it is possible to generate some even harmonics,  
if referred to the fundamental laser wavelength,  $\lambda$

# TIME RESOLVED SPECTROSCOPY

---

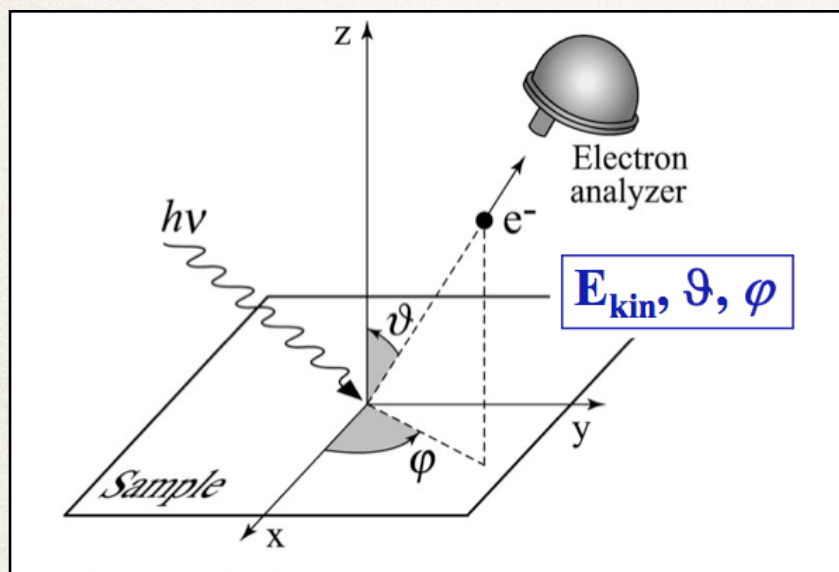
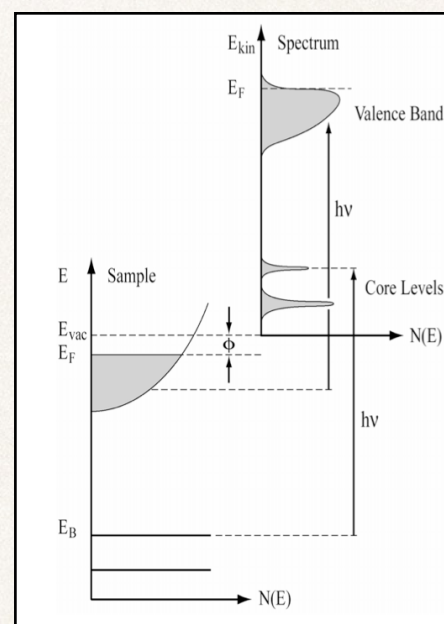


TIME RESOLVED OPTICS  
(REFLECTIVITY/ TRANSMISSION EXPERIMENTS)

ULTRAFAST MAGNETISM

TIME RESOLVED PHOTOEMISSION  
(GASES AND SOLIDS)

# T.R. PHOTOEMISSION BASICS

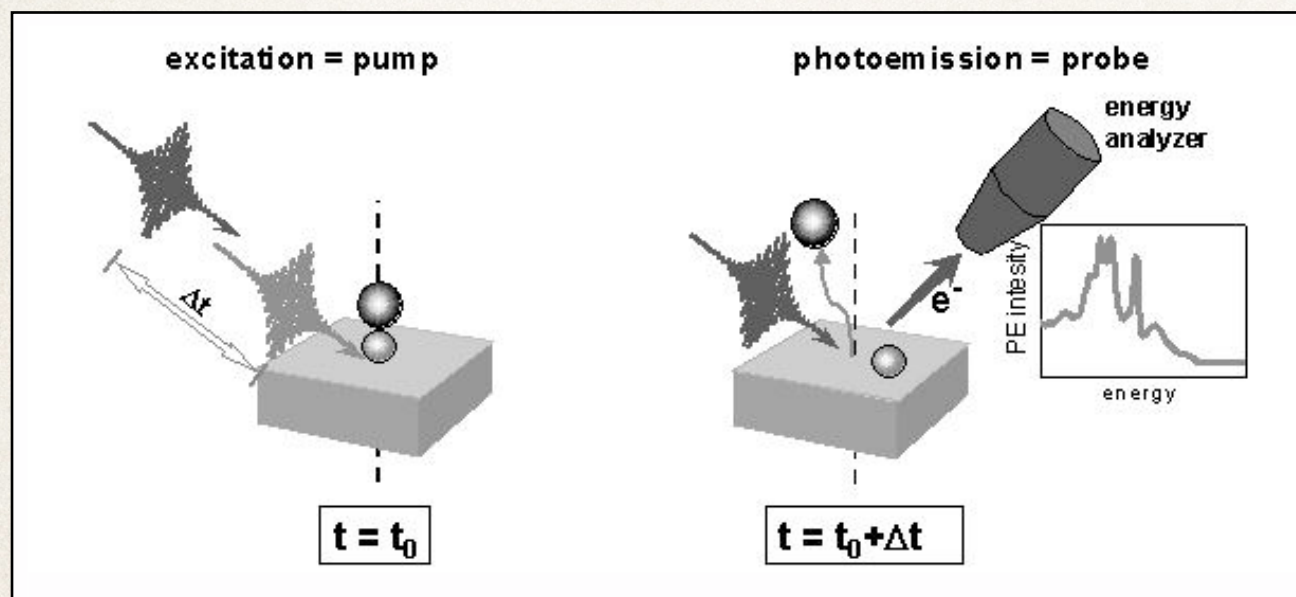


Energy Conservation

$$E_{kin} = h\nu - \phi - |E_B|$$

Momentum Conservation

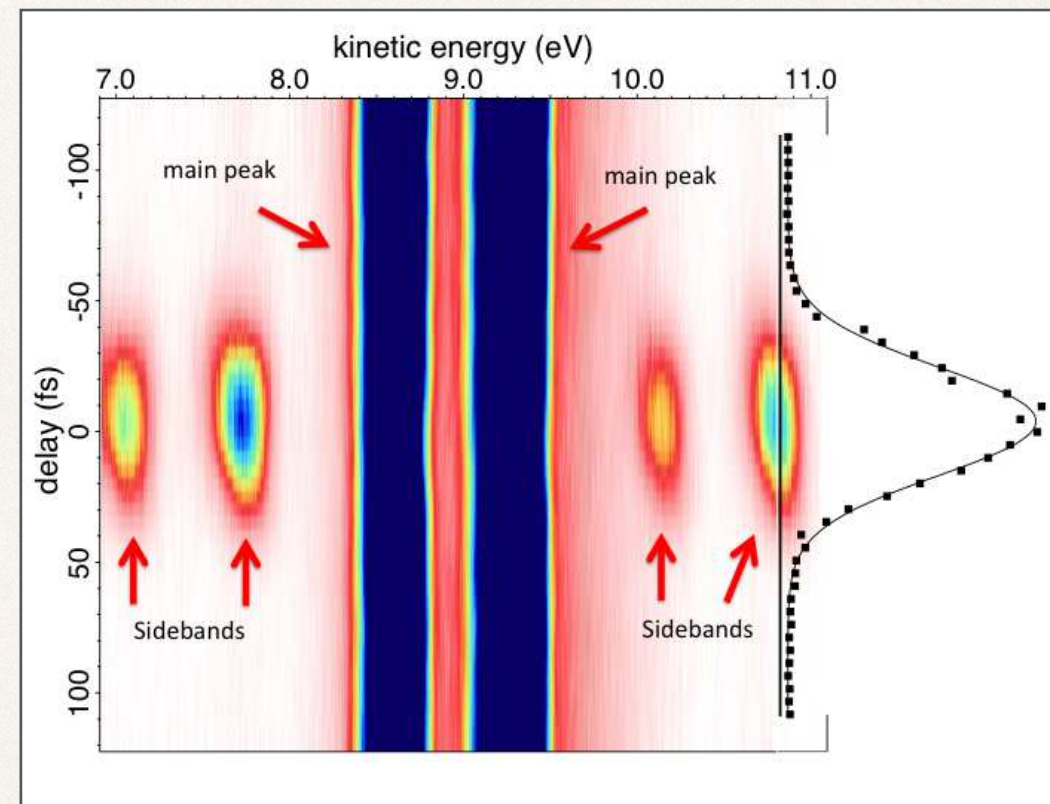
$$\hbar \mathbf{k}_{||} = \hbar \mathbf{K}_{||} = \sqrt{2mE_{kin}} \cdot \sin\theta$$



- ❖ Electron dynamics and surface photochemistry
- ❖ Hot electrons in metals
- ❖ Time resolved band mapping

# PROPERTIES OF HHG LIGHT

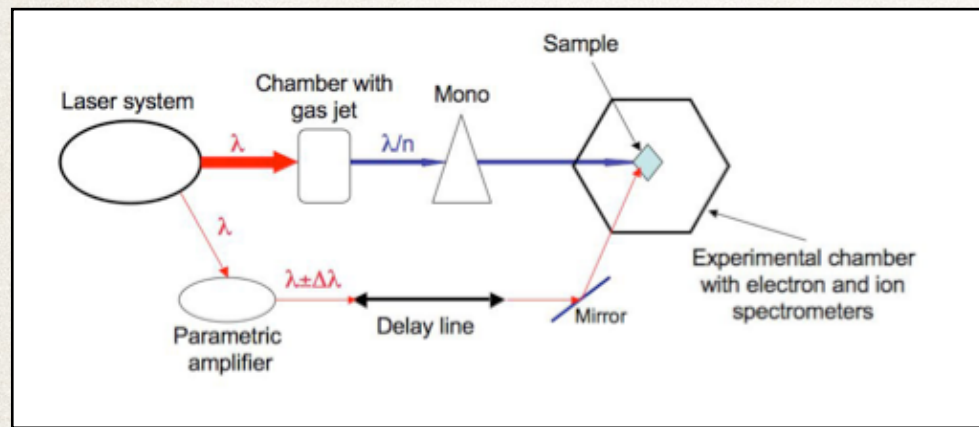
- ❖ Temporal and spatial coherence properties governed by the driving laser
- ❖ Pulse durations typically shorter than that of the driving laser
- ❖ Cross correlation measurement in gas phase (side bands), hemispherical electron energy spectrometer



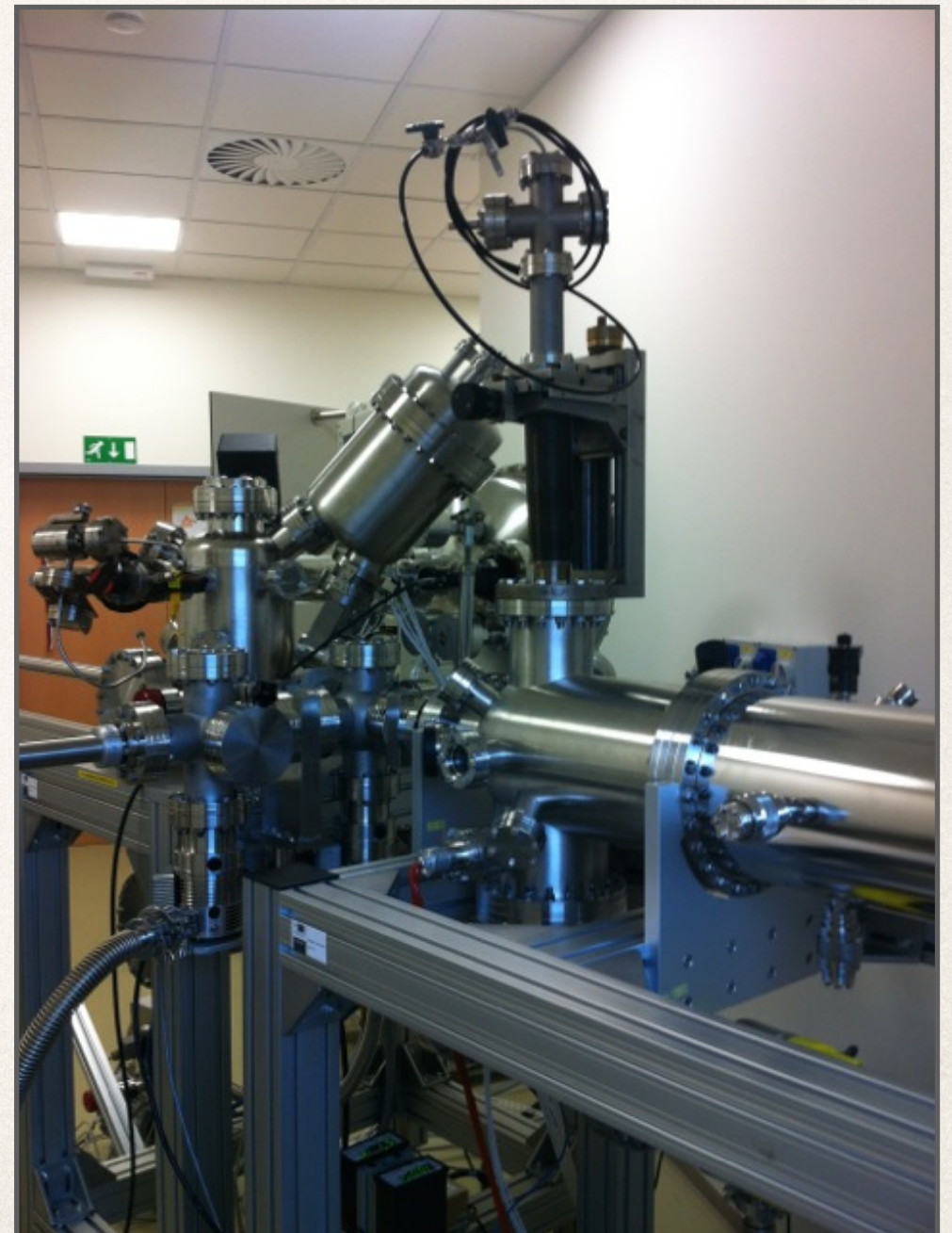
Cross correlation between HH 15 and fundamental Kr 2p

| Grating | Pulse duration (fs) |
|---------|---------------------|
| G200    | $23 \pm 1.2$        |
| G400    | $35 \pm 1.7$        |
| G600    | $35 \pm 1.9$        |

# EXPERIMENTAL CHAMBER



- ❖ Fast Entry
- ❖ Scienta R3000 chamber: Conventional XPS and surface preparation
- ❖ Scienta ARTOF chamber: time and angle resolved Time of Flight electron analyzer
- ❖ Cryogenic manipulator, liquid He closed circuit, 15 K on sample (by nov. 2014)



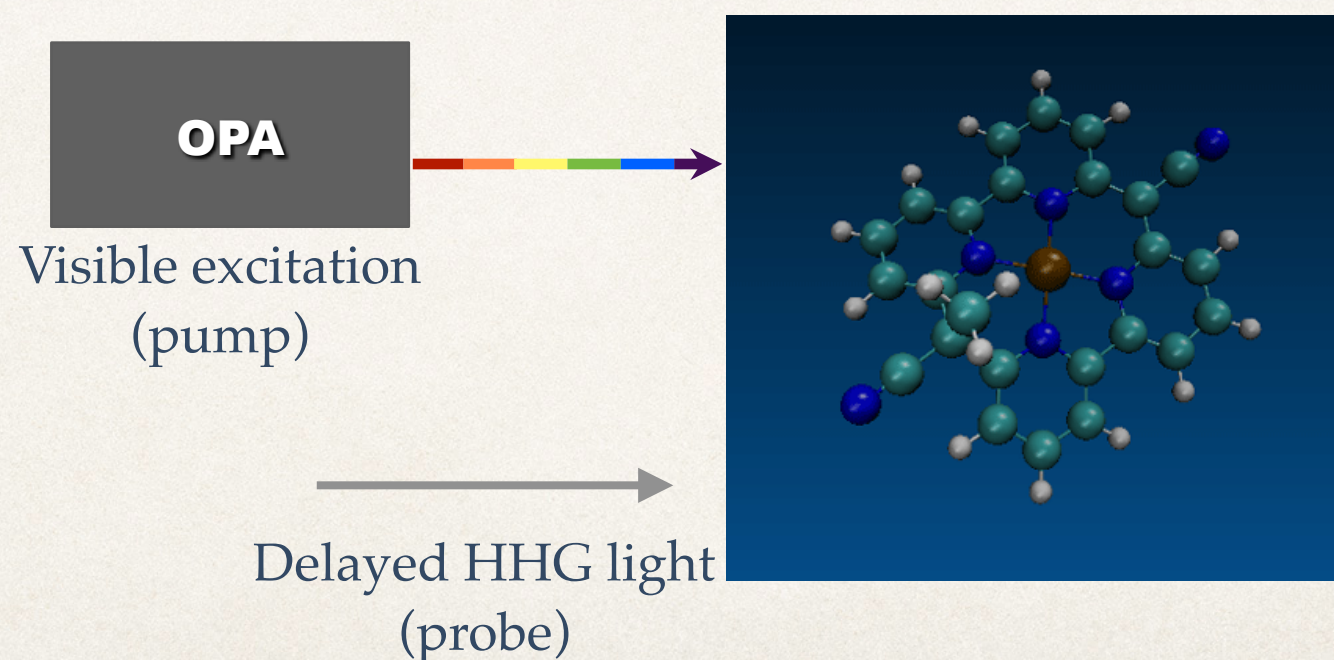
# WHAT WILL BE POSSIBLE TO DO...

---

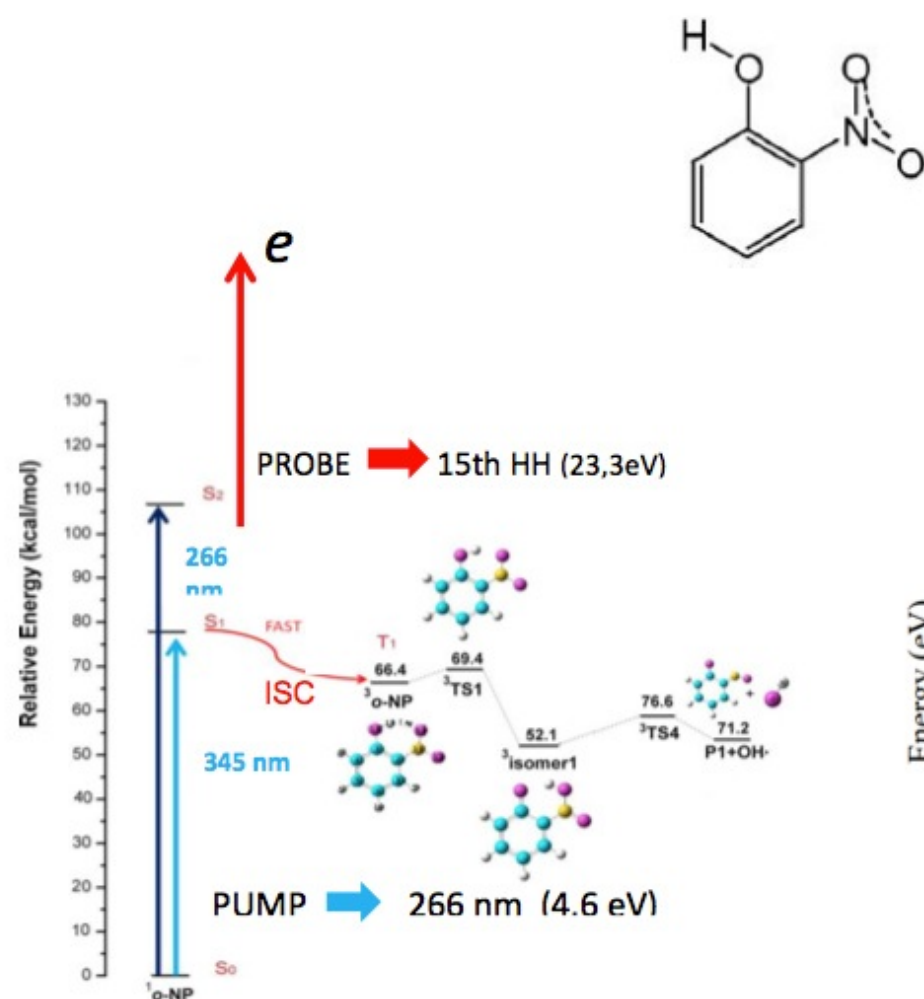
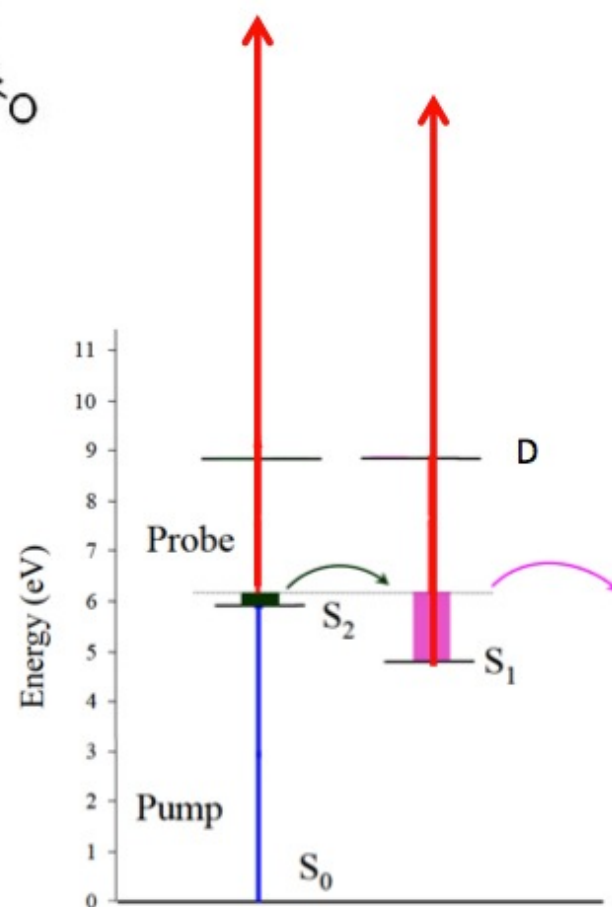
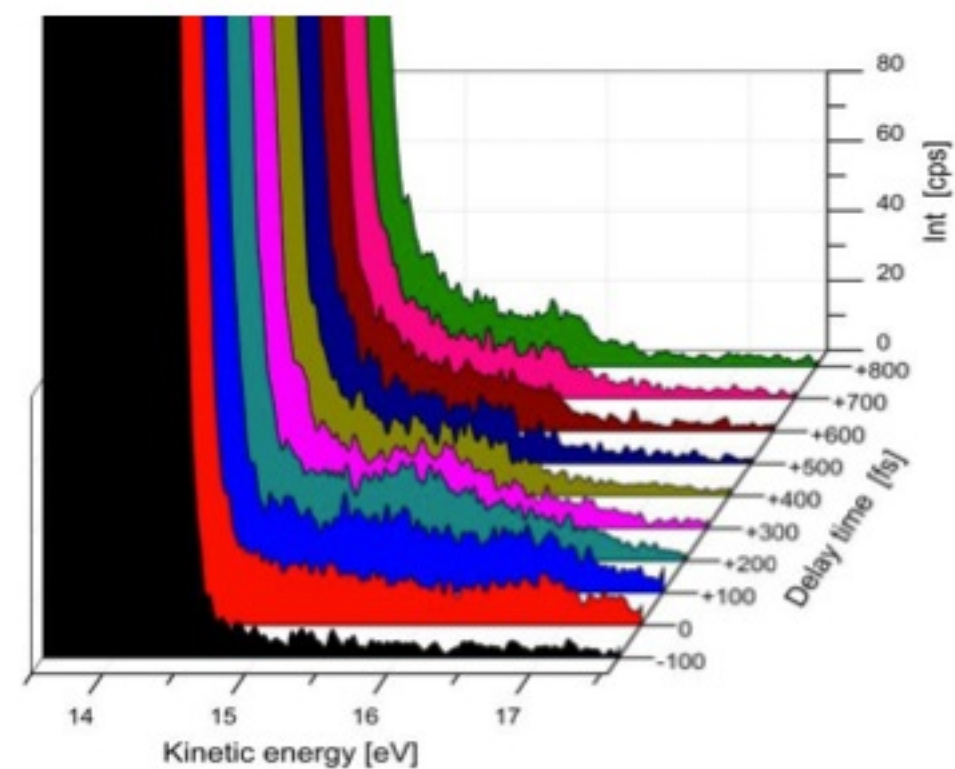
Phorphyrins or phtalocyanines (organic solar cells)

Time resolved investigations of valence band response  
at different light frequencies excitations

Gas phase studies and interface investigation on a noble metal surface



# orthoNITROPHENOL



# CONCLUSIONS

---

- ❖ CITIUS: pulsed photon source in the EUV / soft X-rays region
- ❖ CITIUS: state of art experimental set-up for angle and time resolved photoemission spectroscopy and conventional surface science
- ❖ CITIUS future: open facility for time resolved experiments, unique center in Slovenia

# ACKNOWLEDGEMENTS

---

Giovanni De Ninno - group leader, U.N.G. and Eletttra

Carlo Spezzani - Eletttra

David Gauthier - Eletttra and U.N.G.

Marcello Coreno - C.N.R. and Eletttra

Cesare Grazioli - Univ. Trieste and Eletttra

Alessandra Ciavardini - Univ. Roma and C.N.R.

Luca Poletto - C.N.R. LUXOR Lab.

Paolo Miotti - C.N.R. LUXOR Lab.

Miran Merhar - Univ. Ljubljana

Damian Golob - Kontrolni Sistemi d.o.o.

Rok Vintar - Kontrolni Sistemi d.o.o.

