SPRINT and T-ReX Labs:

user facilities for time, angle, spin resolved photoemission experiments in the extreme ultraviolet regime

SPRINT HHG Lab (FERMI Exp. Hall)

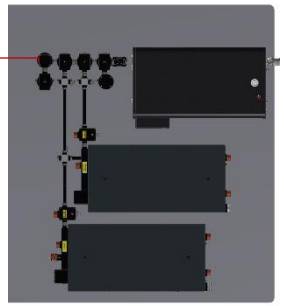
(in collaboration with T-ReX group)

Elettra Sincrotrone Trieste

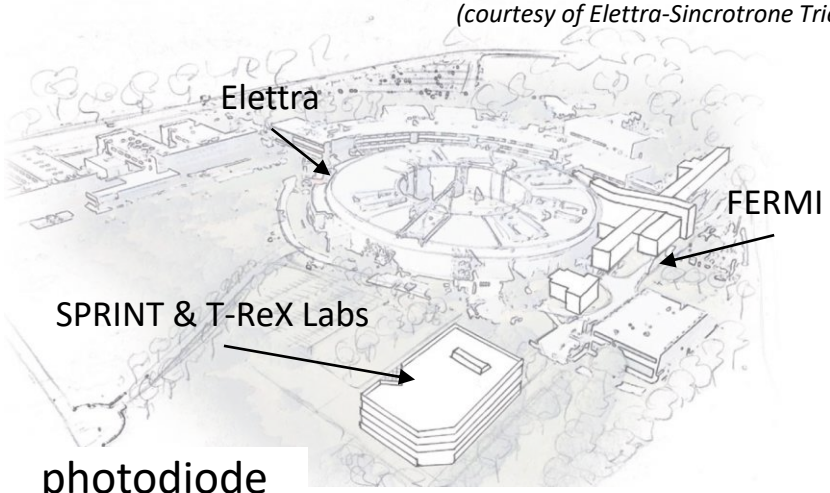
Trieste

Istituto Officina dei Materiali

(courtesy of Elettra-Sincrotrone Trieste)



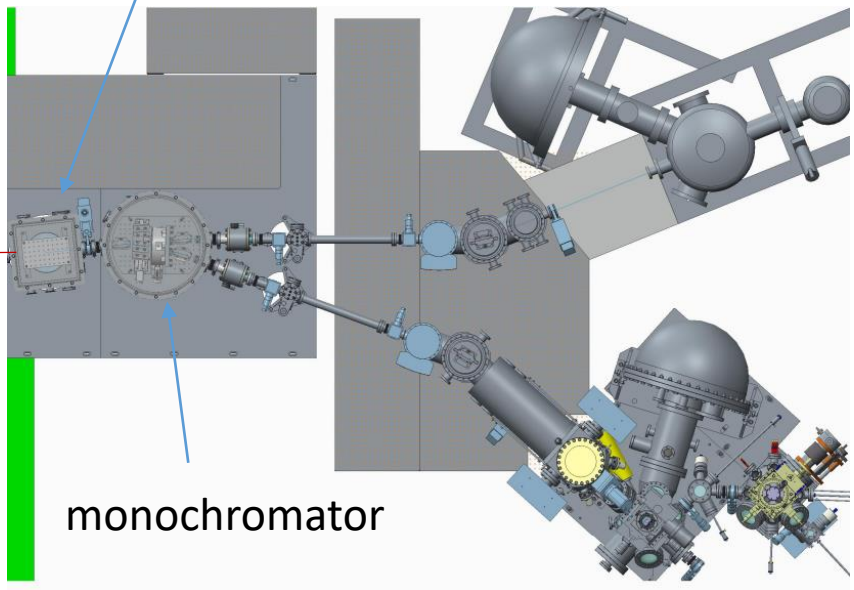
Generation: 10 cm lens
Ar or **Ne** gas



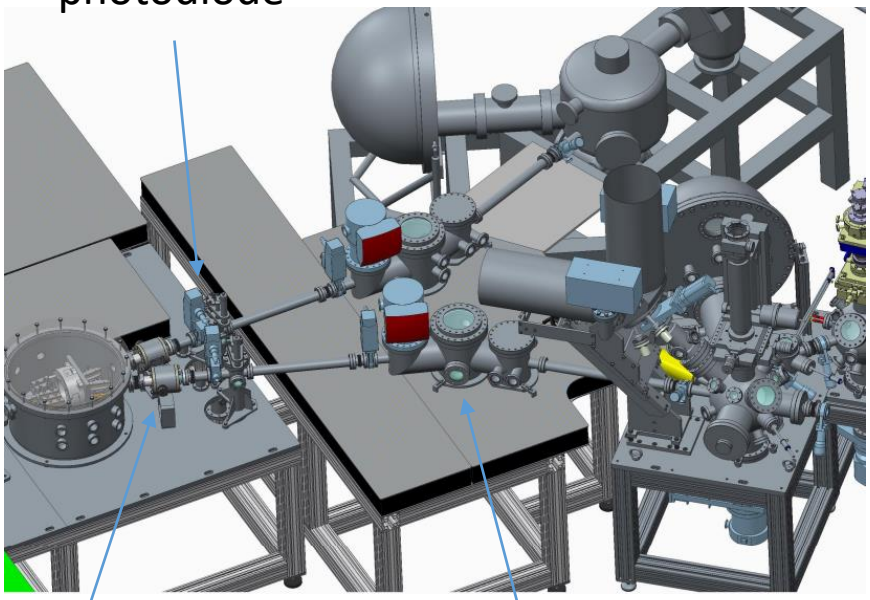
generation chamber

T-ReX

photodiode



monochromator



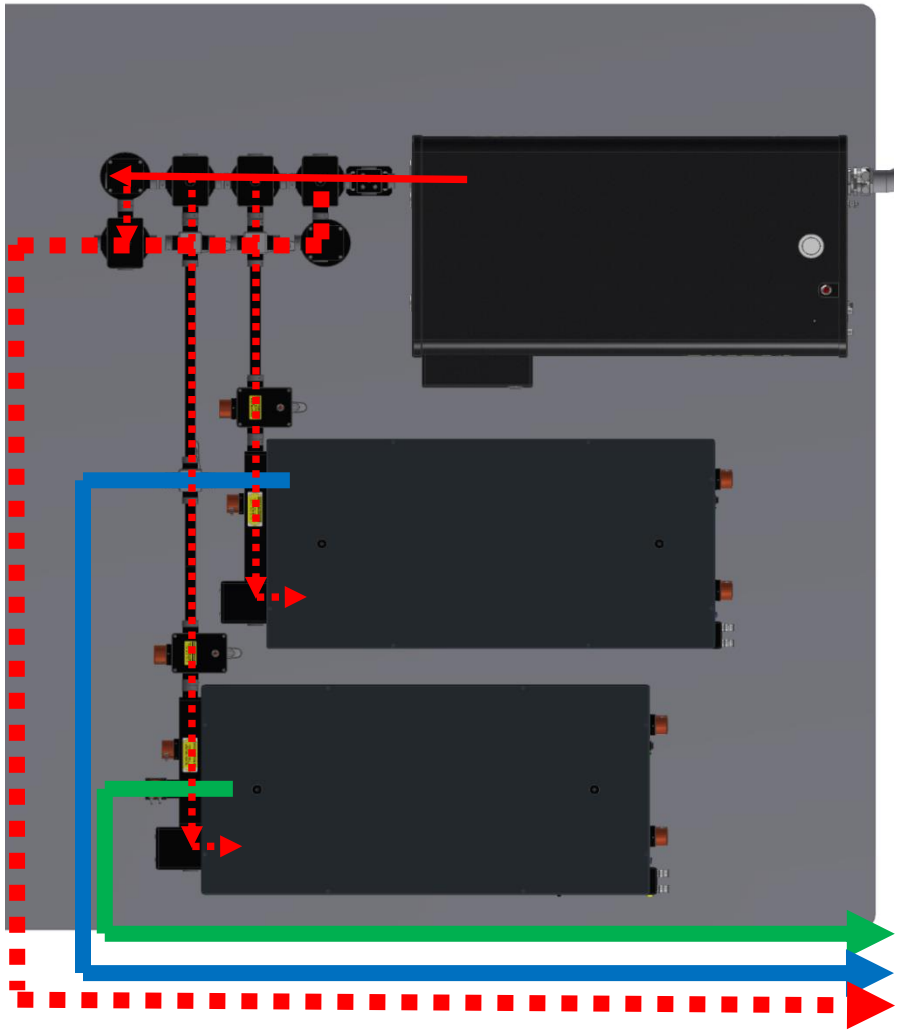
SPRINT

slits

refocalization chamber

SPRINT lab

The Laser System

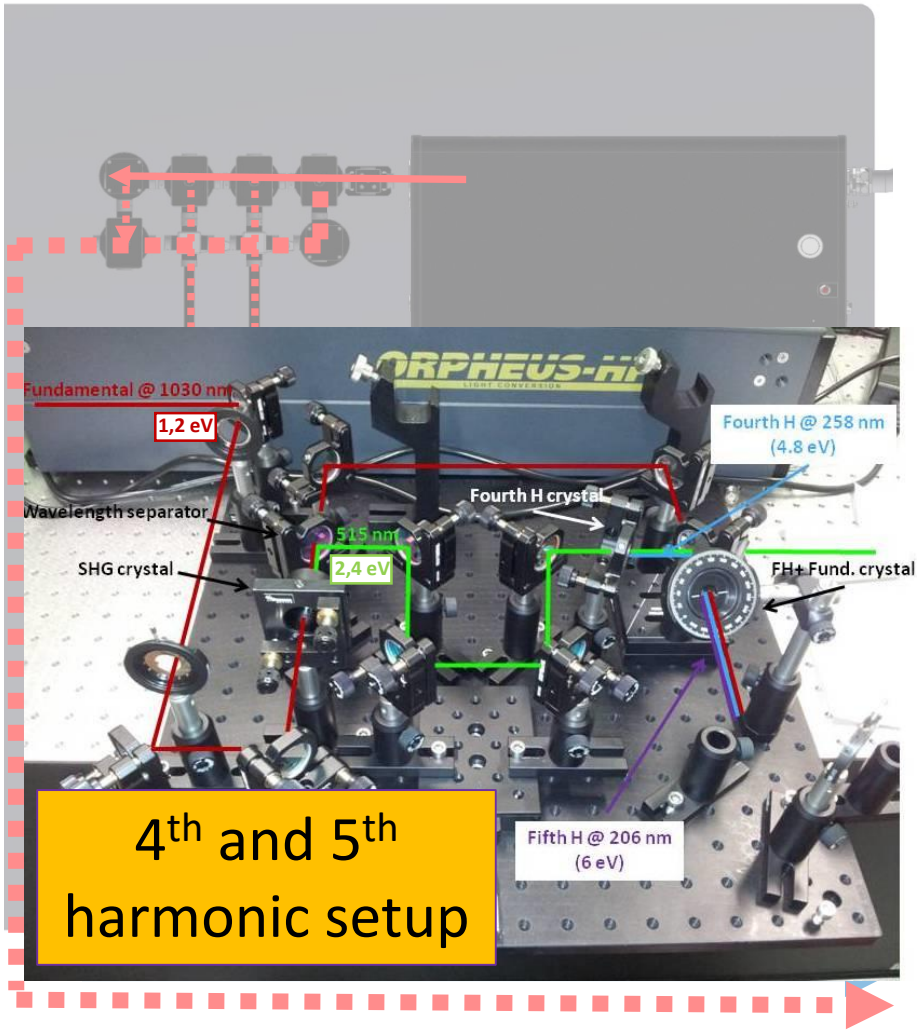


PHAROS: **Yb based laser,**
20 W, pulse duration: 300 fs
rep.rate: 50-1000 kHz,
400uJ/pulse@50 kHz

ORPHEUS-ONE-HP – Mid-infrared
1350 – 2060 nm + 2060 – 4500 nm +
4000-16000 nm (DFG)
Intensity >20% of pump

ORPHEUS-HP – Near-infrared to Visible
630–1020 nm + 1040–2600 nm
Intensity >10% of pump

The Laser System



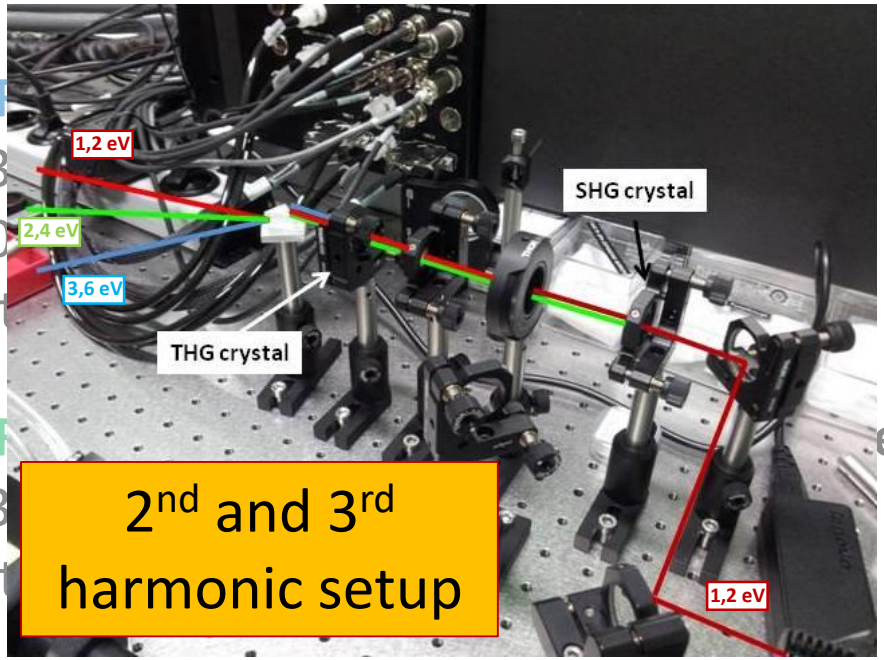
4th and 5th harmonic setup

PHAROS: **Yb based laser,**

20 W, pulse duration: 300 fs

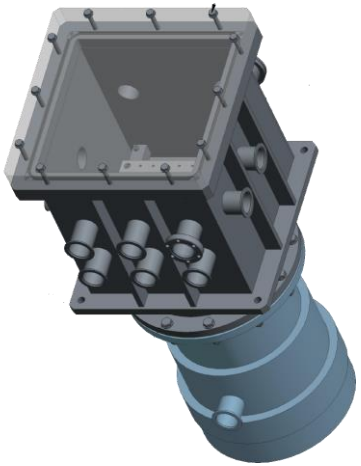
rep.rate: 50-1000 kHz,

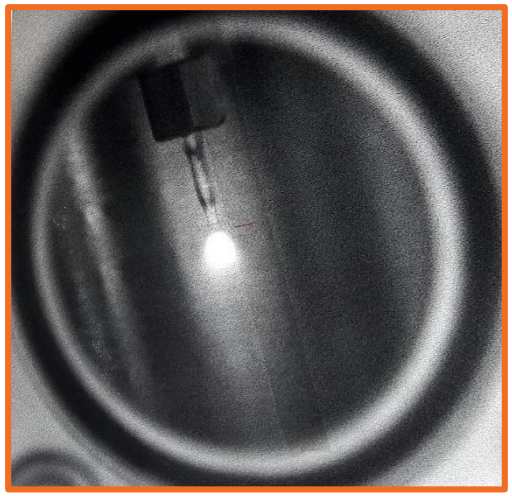
400uJ/pulse@50 kHz

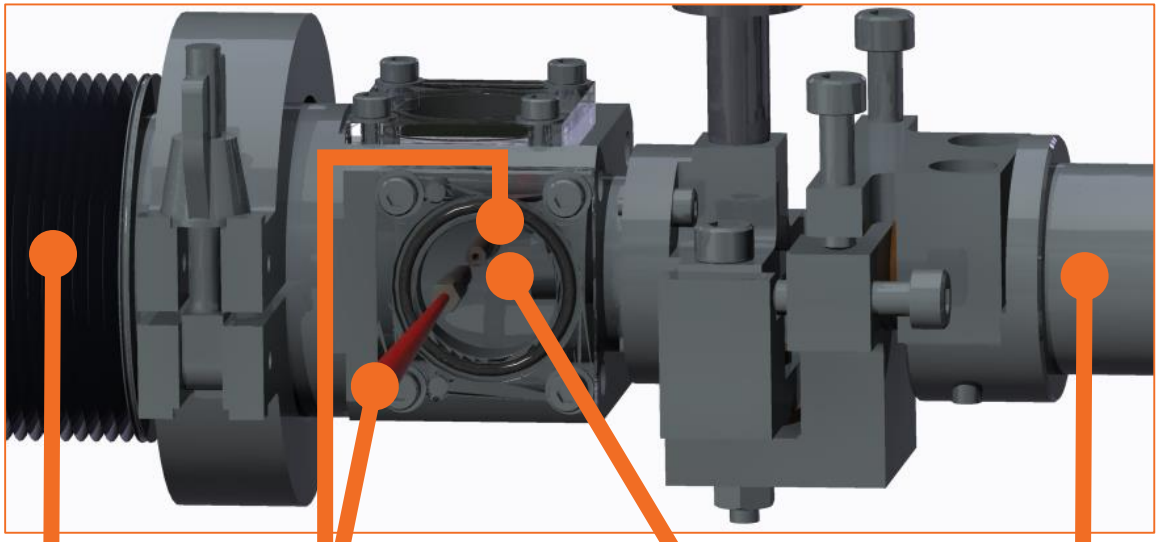


2nd and 3rd harmonic setup

The Generation Chamber







High efficiency pumping

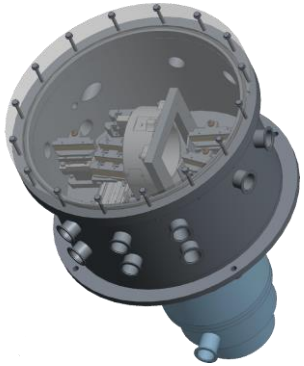
Laser beam inlet and IR+HHG outlet

Gas Capillary Nozzle 30 µm ID

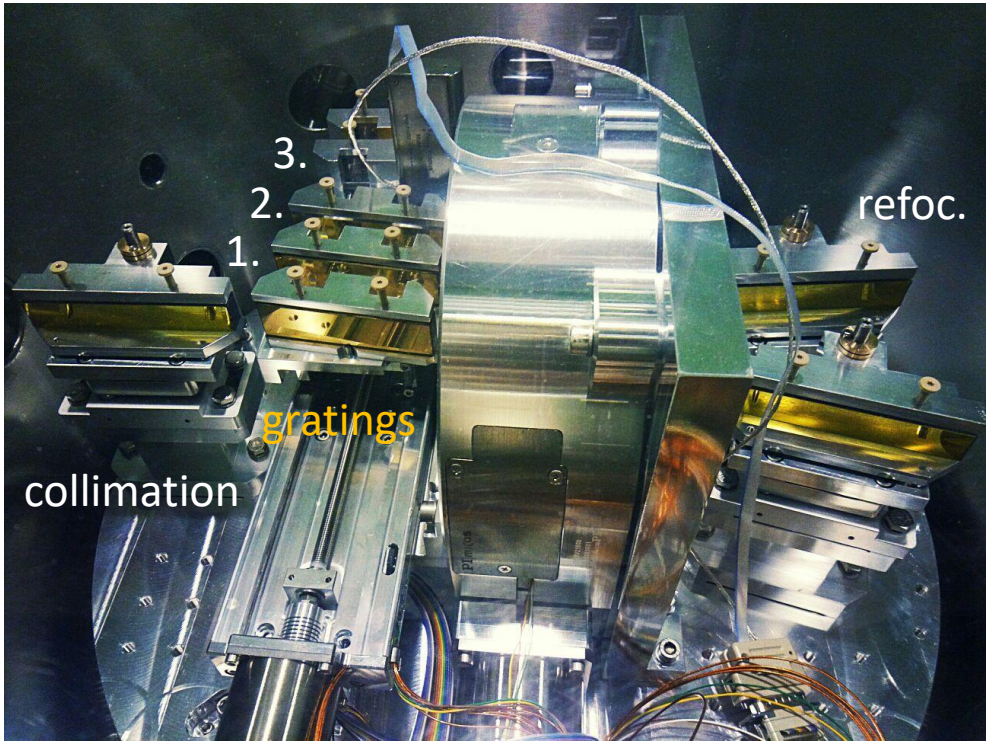
Micrometer precision manipulator

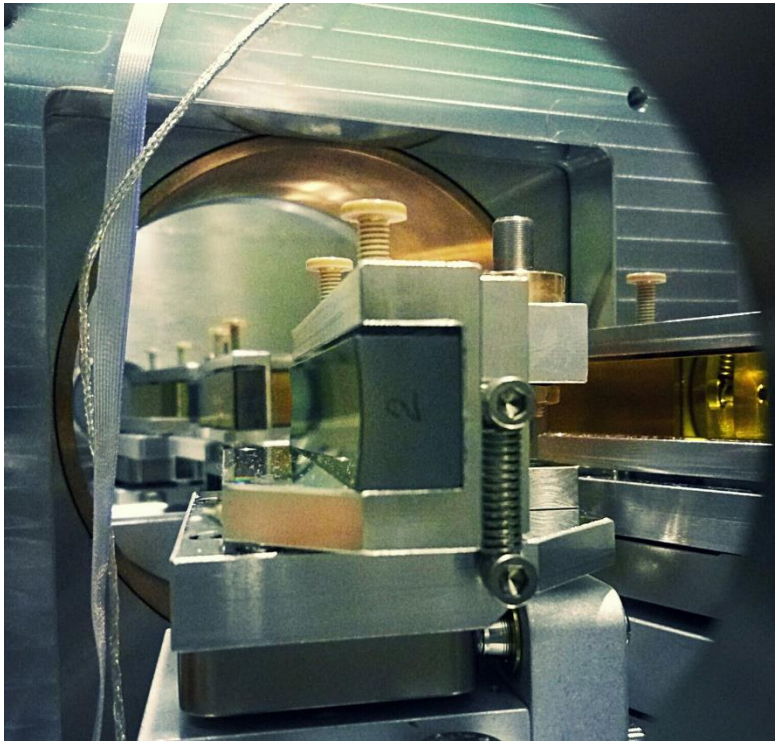
SPRINT lab

The Monochromator

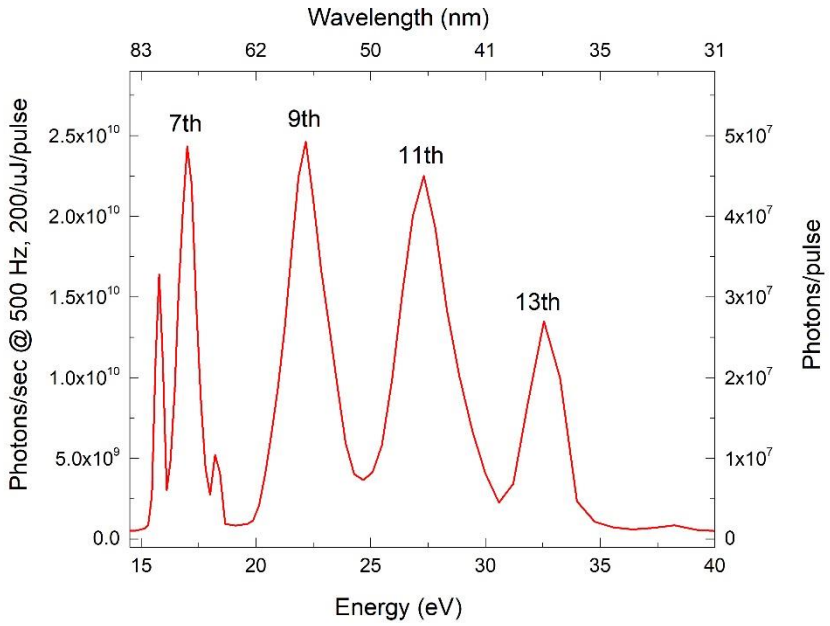


1. 8-30 eV, harmonic separation 4.8 eV, resolution ~2 eV, < 200 fs
2. 30-50 eV, harmonic separation 4.8 eV, resolution ~2 eV, < 200 fs
3. 50-100 eV, harmonic separation 4.8 eV, resolution ~2 eV, < 200 fs





Results, low-energy range



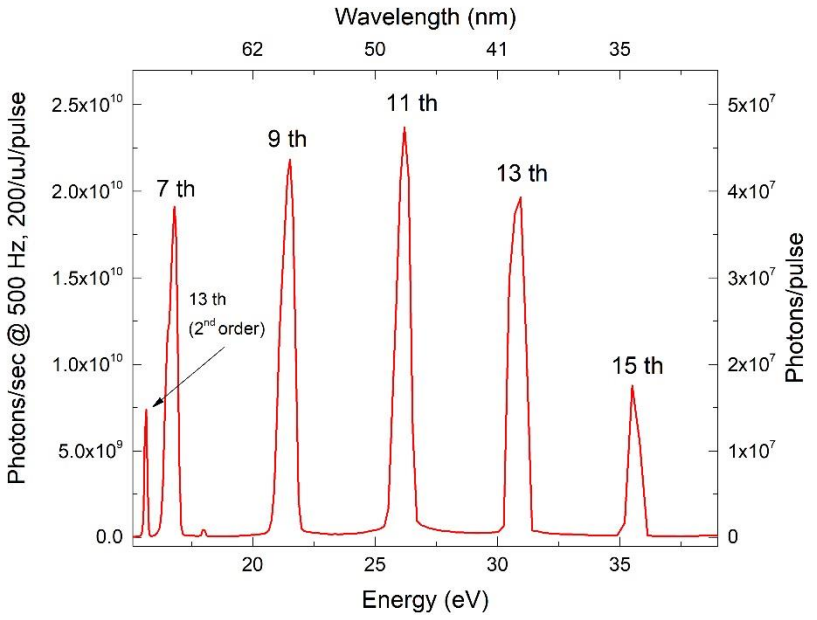
Laser @ 515 nm, 200 uJ/pulse
Ar gas, 4 bar

150 lines/mm grating

Max flux @ 23 eV, 50 kHz, ~2,5x10^{12} photons/s

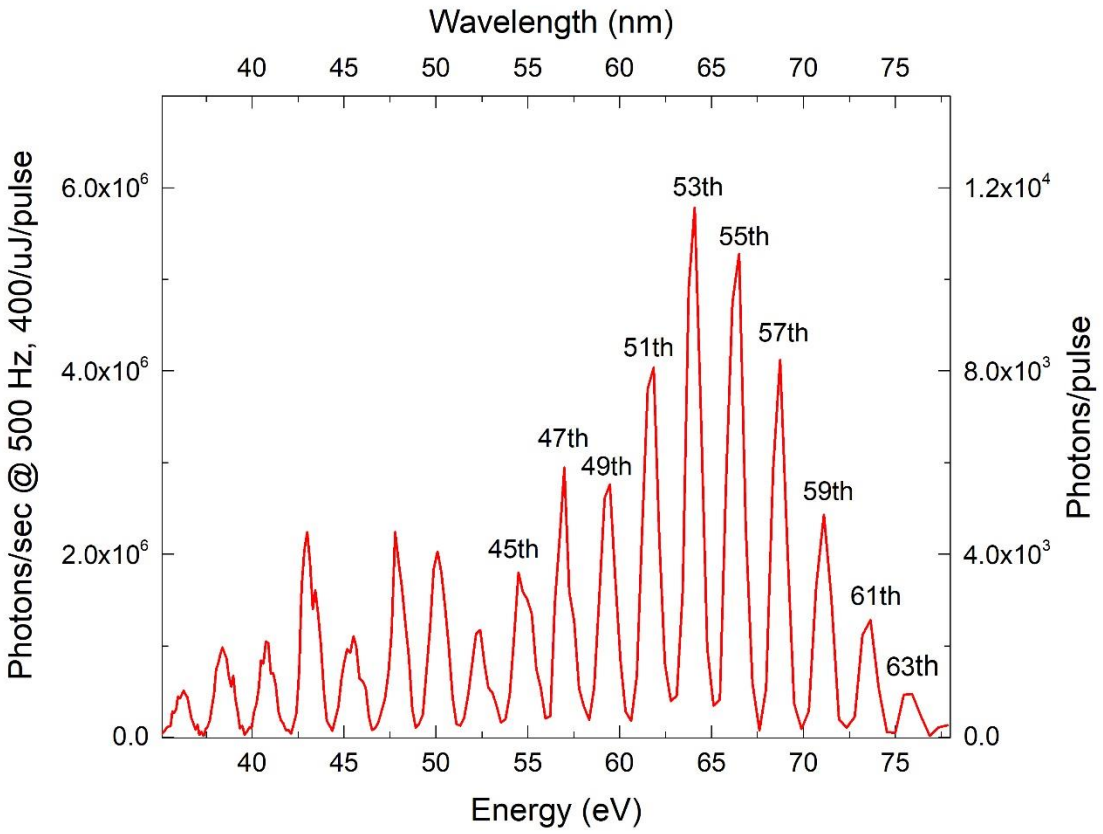
400 lines/mm grating

Max flux @ 26 eV, 50kHz, ~2.5x10^{12} photons/s



SPRINT lab

Results, high-energy range

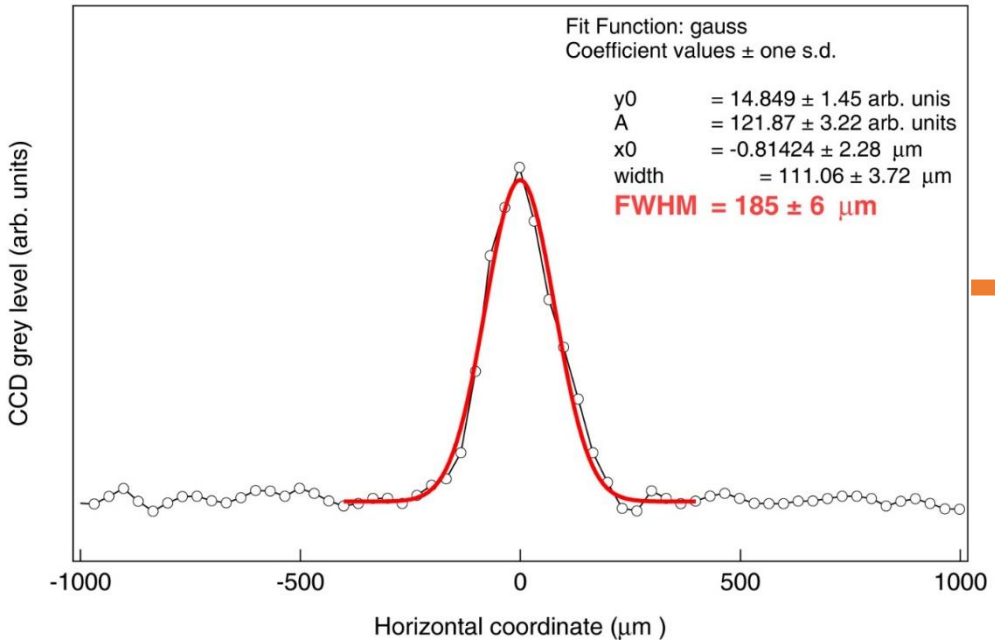


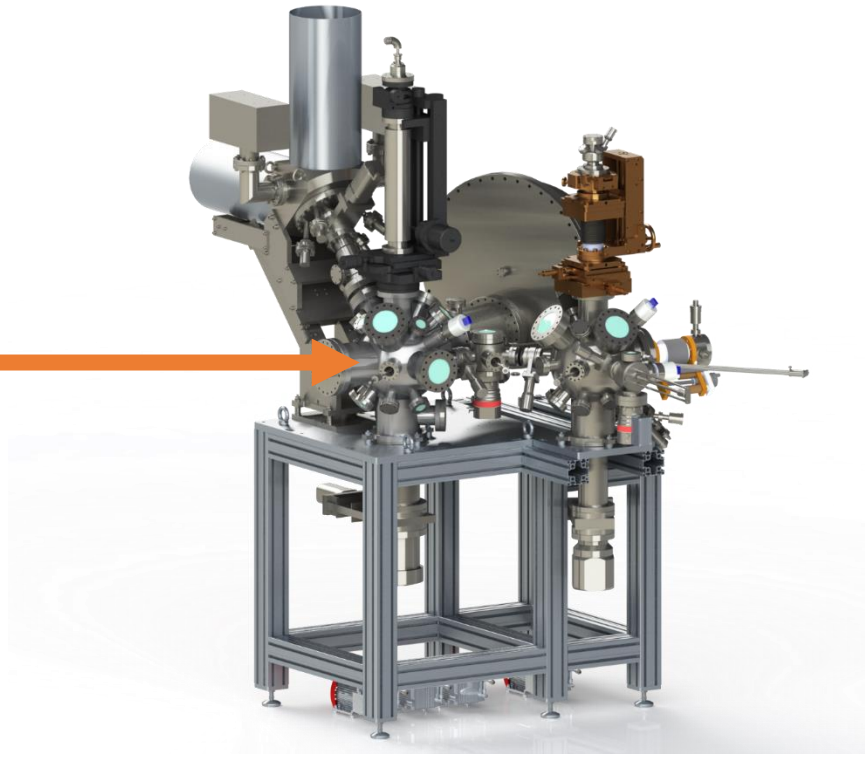
Laser @ 1030 nm, 400 uJ/pulse
Ne gas, 7 bar

1200 lines/mm grating

Max flux @ 63 eV, 50kHz, ~6x10^{8}photons/s

First Full-scale operation run results

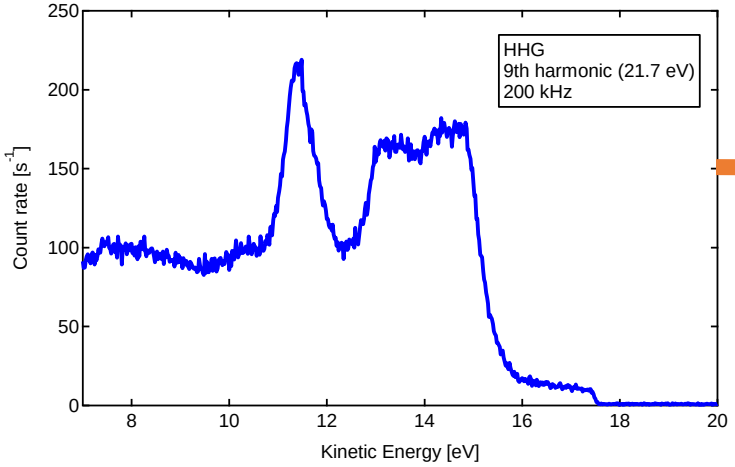


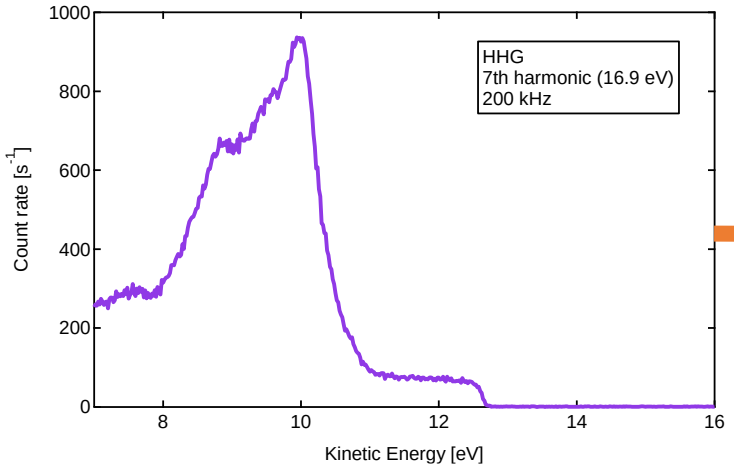


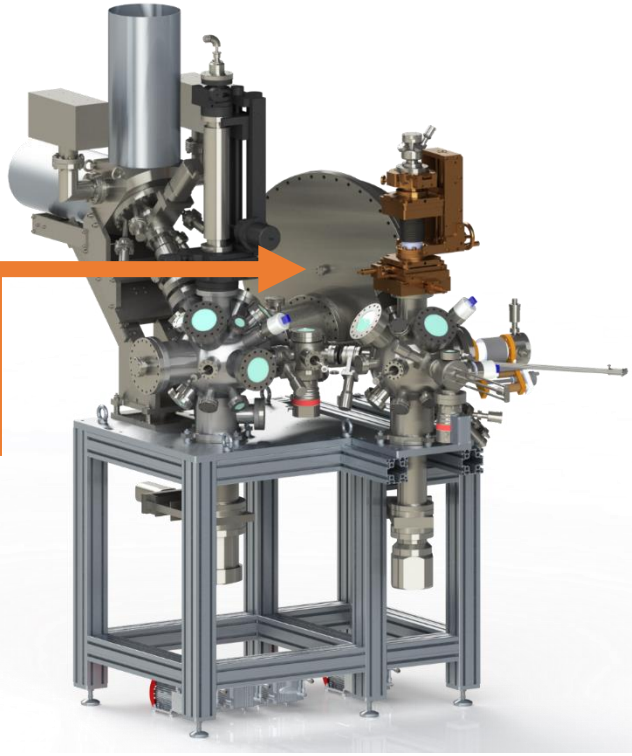
Endstation positioned to match electron analysers and HHG focus

First Full-scale operation run results

Measured first spectrum of valence band photoemission

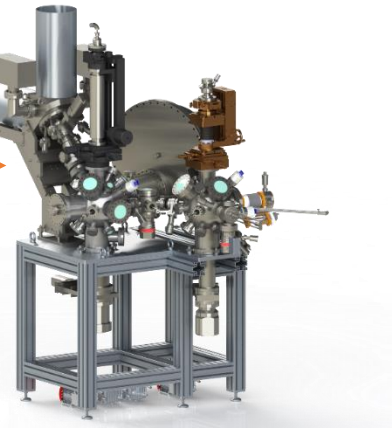


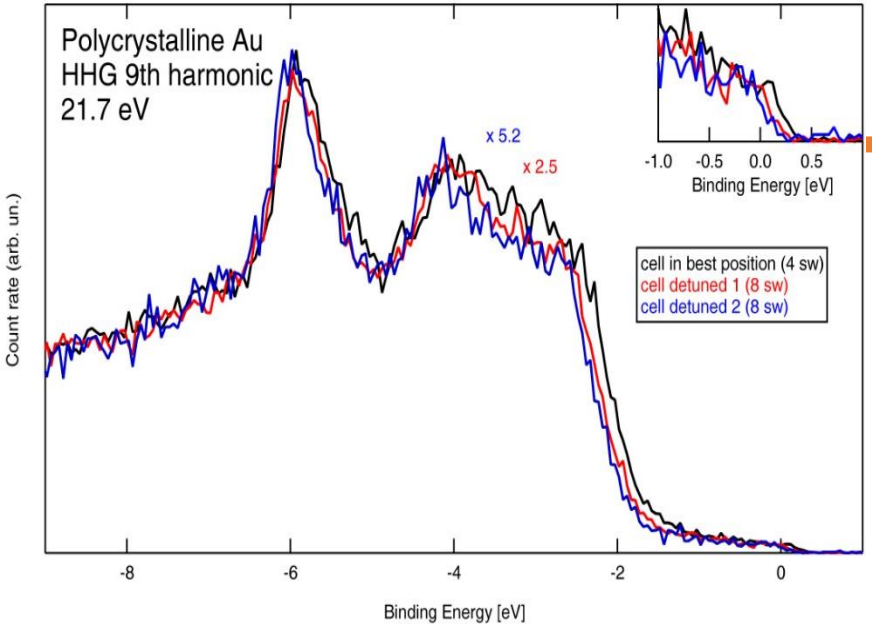


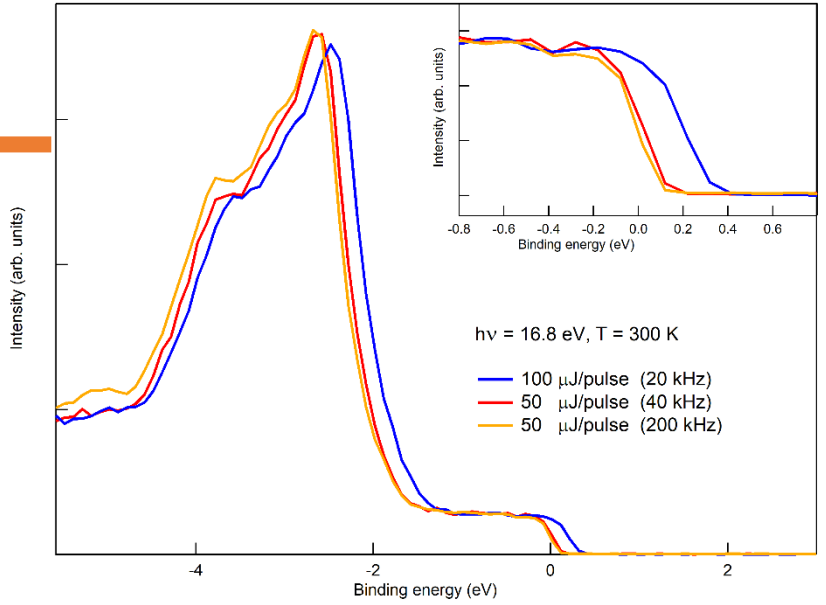


First Full-scale operation run results

Observed effects of space charge due to the high peak photon flux





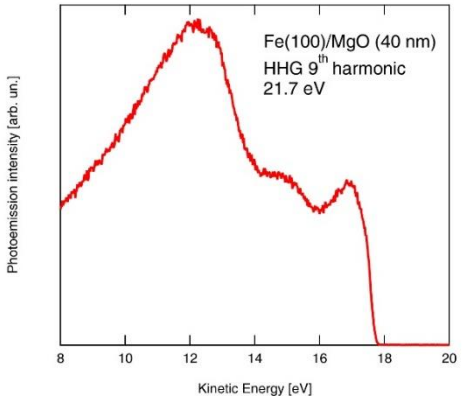


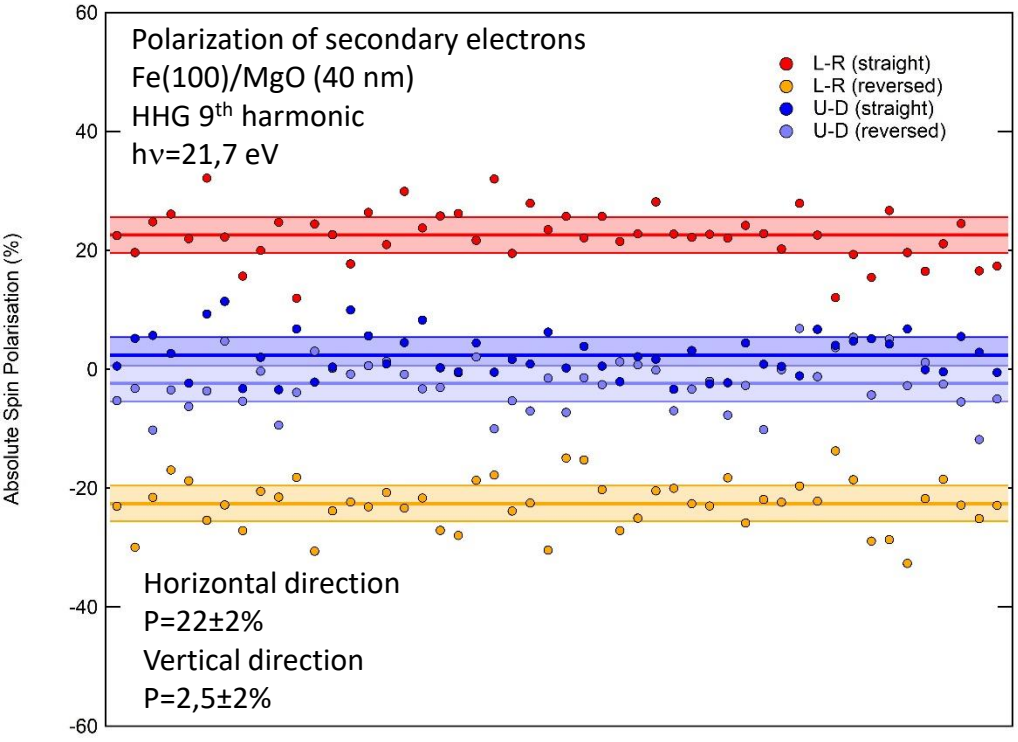
Peak flux reduction by detuning optimal HHG conditions (average flux decrease)

Peak flux reduction by increased rep. rate

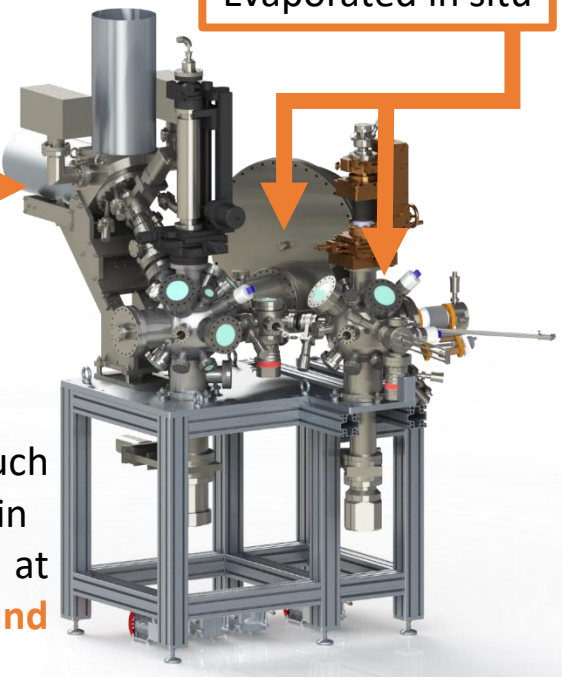
First Full-scale operation run results

Measured first signal of spin polarization of the secondary electrons





Evaporated in situ



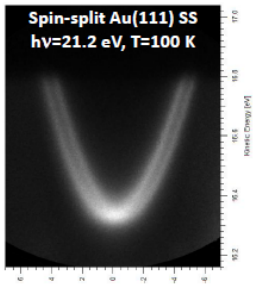
Potential for much higher statistics in **multi-hit mode** at **full peak flux and rep. rate**

The T-ReX TR-ARPES Endstation

Elettra Sincrotrone Trieste

Trieste

Istituto Officina dei Materiali



Double LEED
(main & prep)
For sample orientation

LN Cooling

6 Axis Manipulator

Fast Entry
Sample Garage

TR-ARPES setup at the T-ReX laboratory (FERMI, Elettra)

Specs Phoibos 225
Hemispherical Analyzer

LEED

LEED

Preparation
Chamber

Main
Chamber

Laser source input

Preparation Chamber:

* Ar Sputtering
* Annealing (1000 C)
* Cleaving
* Simple evaporation

T-ReX Research Group

Laser (non-equilibrium):

* Probe: 6.2 eV (Ti:Sa FHG)
  8.5 eV, 9.3 eV (6HG)
  HHG, 15-35 eV (new addition)
* Pump: 1.5 eV, 3.1 eV, 0.5-1.2 eV

SPECS Phoibos 225

Photoelectron Analyzer

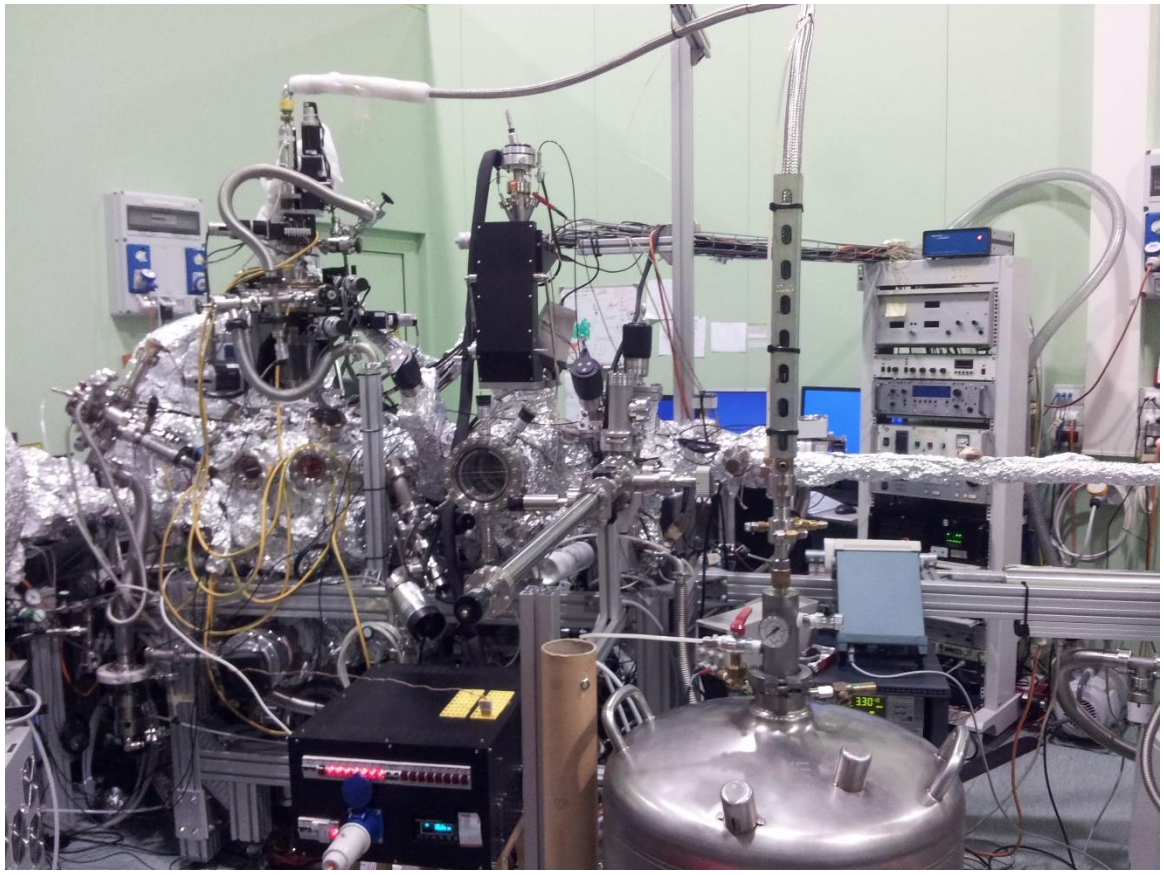
~20 meV energy resolution
±18° acceptance ('SWAM')

The TR-ARPES Endstation, a real view…

Elettra Sincrotrone Trieste

Trieste

Istituto Officina dei Materiali



MAIN CHAMBER

SPECS Phoibos 225 hemis. analyzer
(angular res. 0.1°, energy res. 20 meV)
- DelayLine Detector (DLD), low noise
- Six DOF cryo-manipulator (T>35 K)
- $<10^{-10}$ mbar
  - LEED
  - He-I lamp, 21,2 eV

PREPARATION CHAMBER
- Sputtering and annealing (T<1000°C)
- LEED
- RGA
- Cleaving in UHV via scotch tape or pin
- $<10^{-10}$ mbar
- Fast entry (10^{-7} mbar in 30')
- Users sample growth possible

LASER SOURCES
- FHG at 6.2 eV (up to 700 kHz)
- 8.5-9.3 eV in Xe (up to 250 kHz)
- HHG (>50 kHz)
- TR-OPTICS on same crystal
- 2PPE
- Polarization control
- OPA pumping up to mid-IR

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6HG sources at 8.5-9.3 eV source

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Trieste

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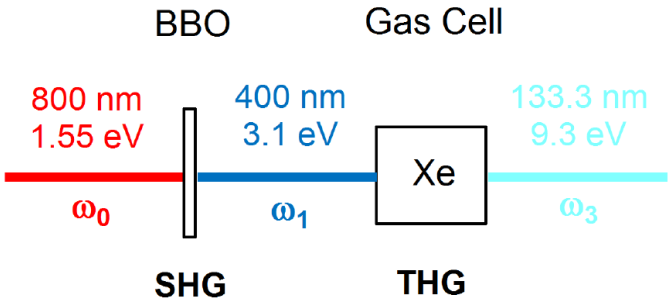
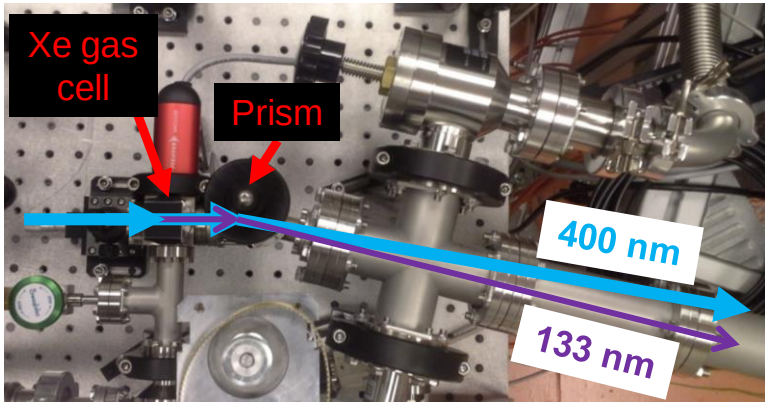
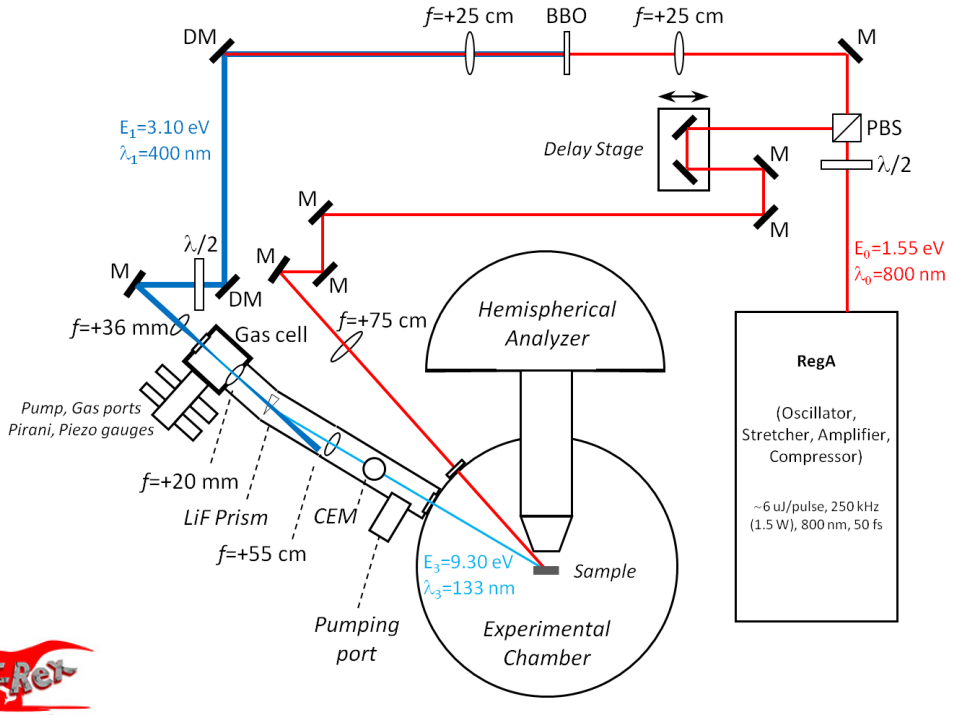
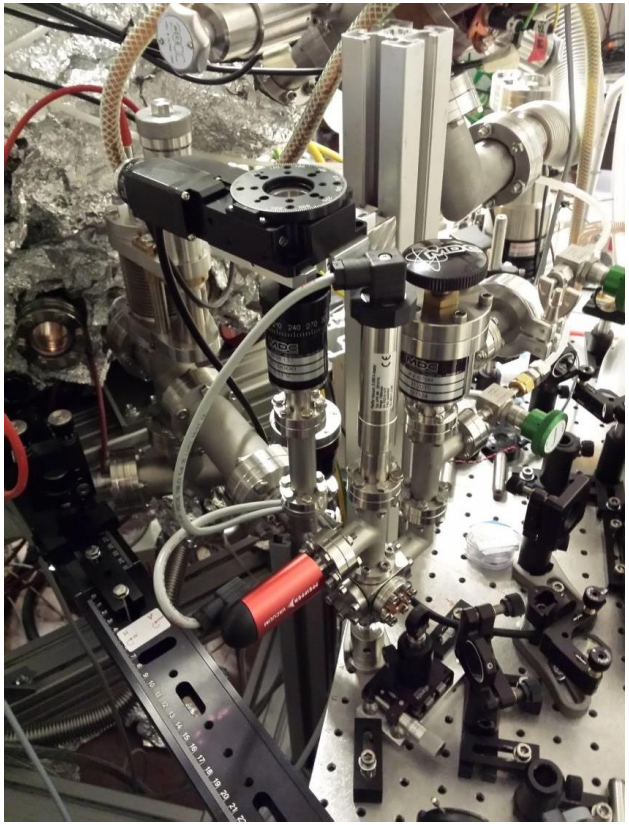
Driven by RegA (250 kHz), 6HG of 800 nm: 133 nm (9.3 eV)
Driven by Pharos+OPA (50 kHz), 6HG of 870 nm: 145 nm (8.5 eV)
Under development: 9HG of 1035 nm: 115 nm (10.8 eV)









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Results by TR-ARPES at T-ReX

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Trieste

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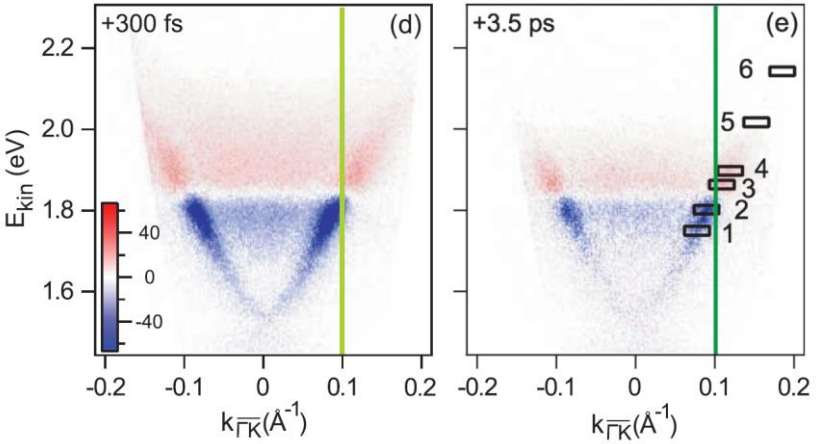
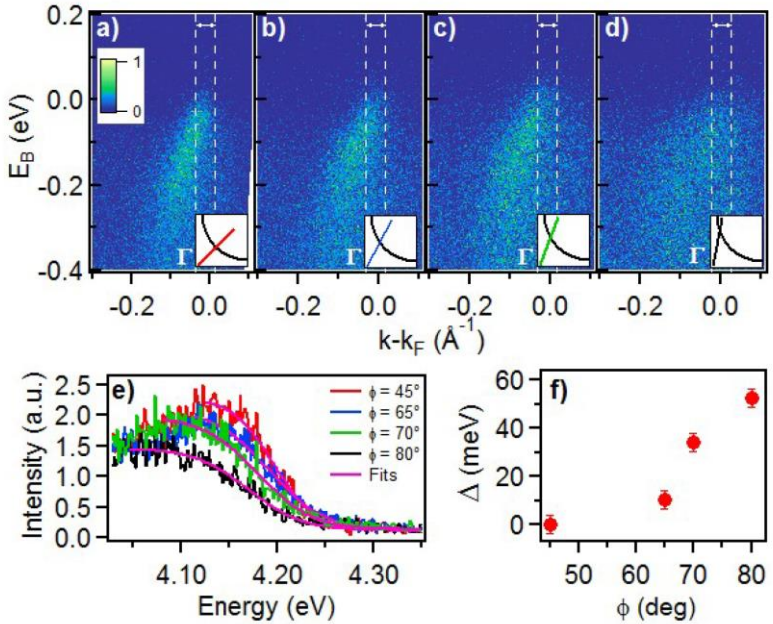
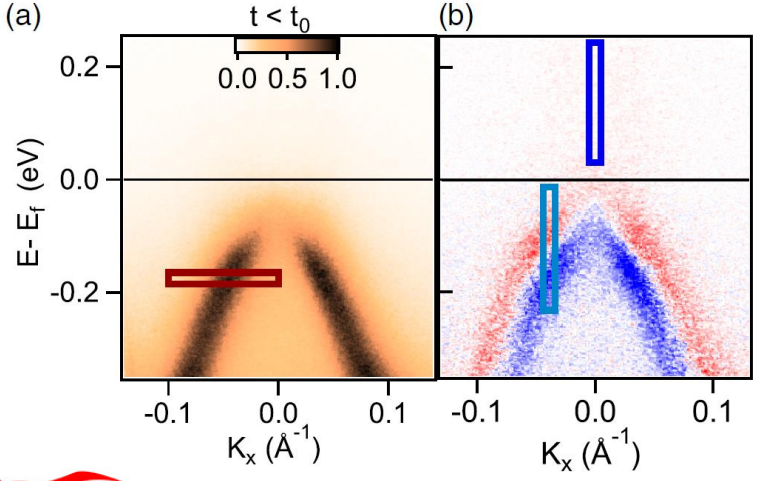
Electronic-temperature dynamics on Bi_2Se_3 TI



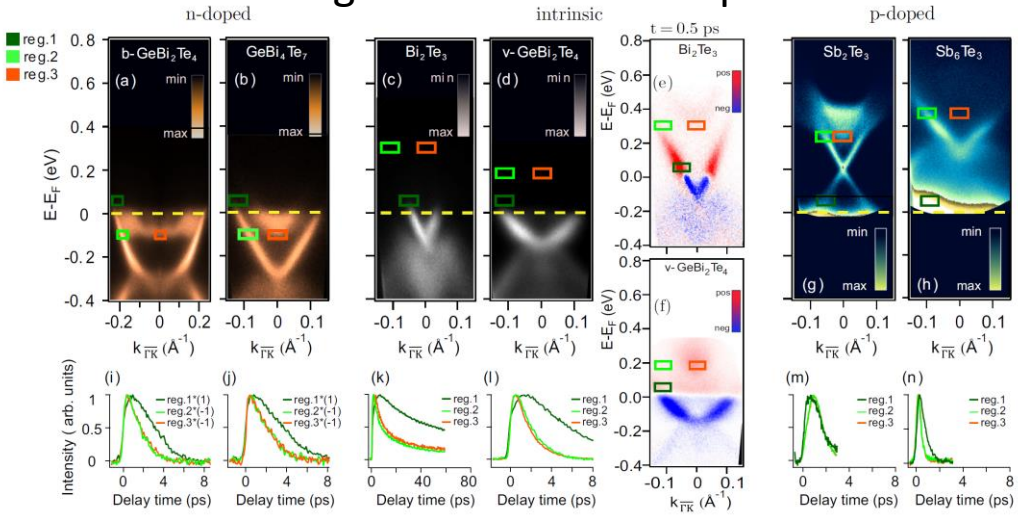
Full BZ mapping of Bi2212 HTSC (by 8.5 eV)



Optical control of bandstructure in $ZrTe_5$



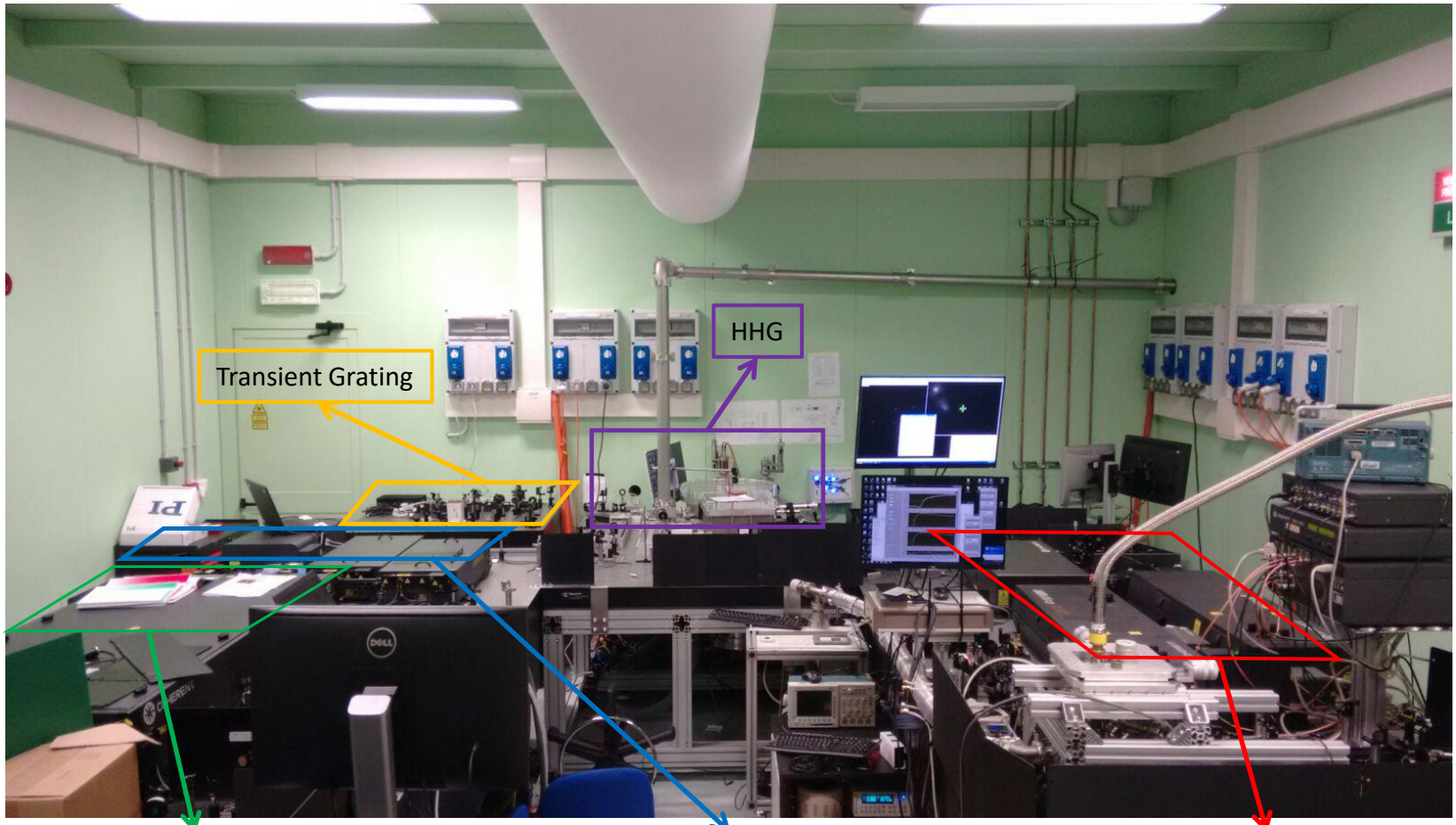
Scattering mechanisms in doped TIs



T-ReX Research Group

The Laser Hutch

3 complementary sources are available for users



Coherent Legend

1 or 5 kHz rep. Rate
8 mJ/pulse at 1 kHz, 2.5 mJ/pulse at 5 kHz
λ=800 nm
<40 fs
Synchronizable

LightConversion Pharos

0-1 MHz operation
400 uJ/pulse at <50 kHz
20 W for >50 kHz
λ=1030 nm, 290 fs
2 OPAs (630-2600 nm, 1350-4500 nm)

Coherent RegA

100-700 kHz rep. Rate
λ=800 nm, <50 fs
7 uJ/pulse at 250 kHz, 4 uJ/pulse at 700 kHz
OPA (1150-2600 nm + DFG)
Synchronizable

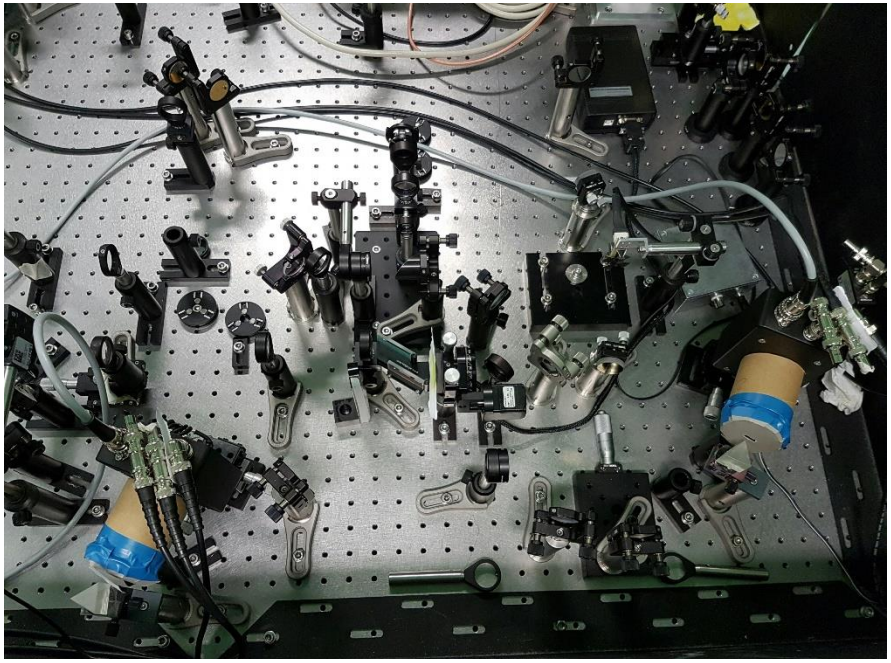
The T-ReX TR-OS Setup at T-ReX

Elettra Sincrotrone Trieste

Trieste

Istituto Officina dei Materiali

Setup for time-resolved optical spectroscopic measurements with broadband detection

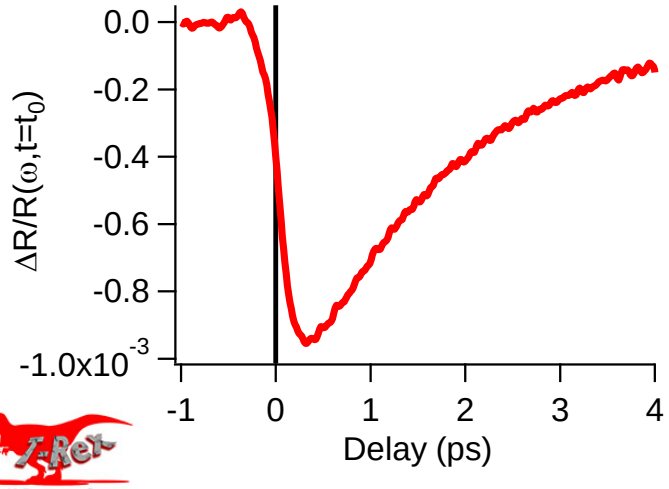


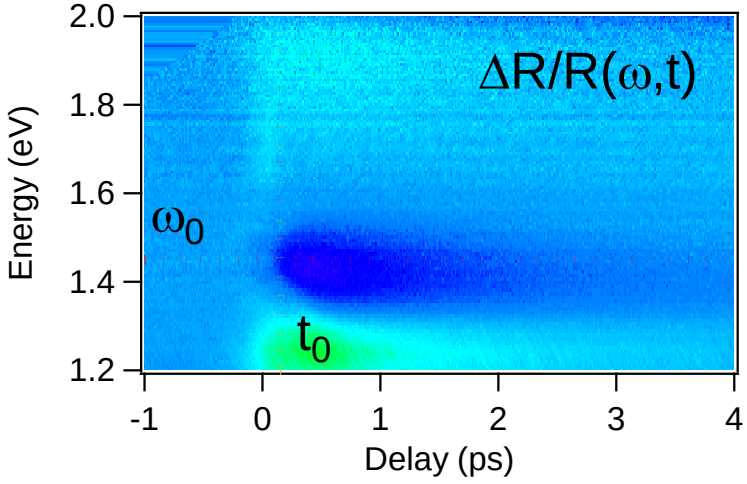
Mainly driven by RegA (up to 700 kHz)

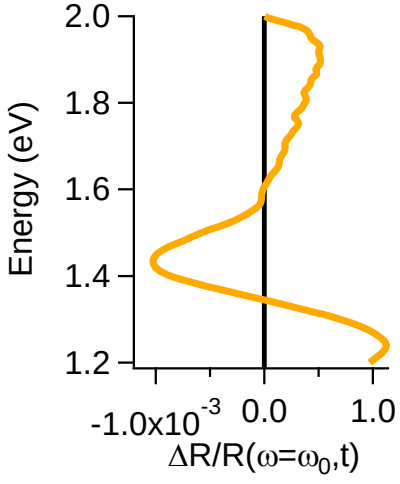
Probe:
* 800 nm, 400 nm
* OPA Probe: 1100-2500 nm and its SHG
* Supercontinuum (VIS, IR):
  350-1000 nm with Si detectors
  500-1700 nm with InGaAs detectors

Pump:
* 800 nm, 400 nm
* OPA Pump: 1100-1450 nm

High S/N: $>10^5$
Fast pump modulation (125 kHz)
Cryostat 4-325 K



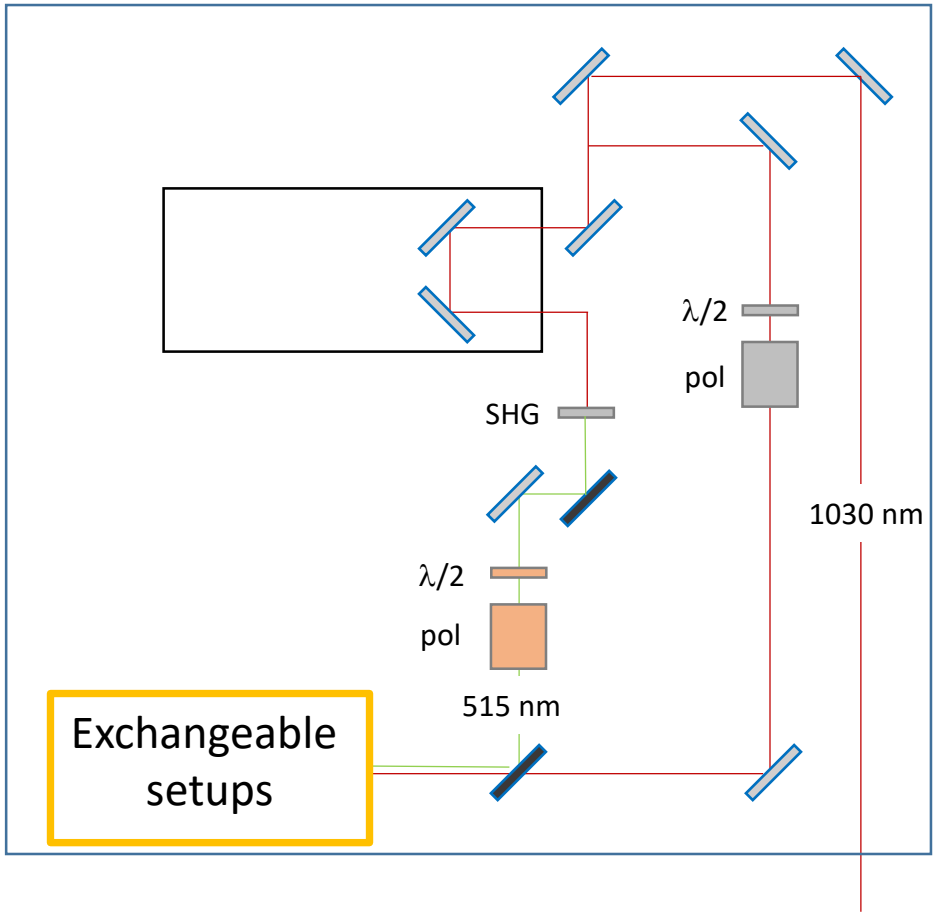




T-ReX Research Group

On going developments

Pump-probe spectroscopies



Currently:

Transient grating setup
(software for acquisition on progress)

Application:

- Magneto-elastic waves:
  Fe1-xGax on SrTiO3
- Electron dynamics on TCO

Other possible setup:

Time Resolved Magnetic Optical Kerr effect

People

SPRINT Group

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SCIENTIST IN CHARGE
Giancarlo Panaccione

SCIENTIST IN CHARGE
Riccardo Cucini

POST-DOC CNR
Tommaso Pincelli

POST-DOC CNR
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TECHNOLOGIST
Andrea Fondacaro

UNIVERSITÀ DEGLI STUDI DI MILANO MASTER STUDENT
Alessandro De Vita

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Simone Peli (POST-DOC)
Damir Kopic (PhD Student)
Davide Soranzio (PhD Student)
Andrea Sterzi (POST-DOC, former)
Daniel Payne (POST-DOC, former)

IFN – CNR Group

(optics and monochromator design)

Luca Poletto (COORDINATOR)
Fabio Frassetto (SCIENTIST IN CHARGE)
Federico Miotti (PHD STUDENT)

IOM – CNR Group

Aleksander De Luisa (ENGINEER)
Damjan Krizmancic (SOFTWARE DEVELOPER)
Federico Salvador (TECHNOLOGIST)