# LASERLAB-EUROPE

The Integrated Initiative of European Laser Research Infrastructures IV

**Grant Agreement number: 654148**

WP4 – Scientific and Technological Exchanges

Deliverable 4.8
Second and open joint JRA Meeting

Lead Beneficiary: POLIMI

Due date: M48
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| *Deliverable Type* | |
|---|---|
| R = Report<br>DEM = Demonstrator, pilot, prototype, plan designs<br>DEC = Websites, patents filing, press & media actions, videos, etc.<br>OTHER = Software, technical diagram, etc. | OTHER |
| *Dissemination Level* | |
| PU = Public, fully open, e.g. web<br>CO = Confidential, restricted under conditions set out in Model Grant Agreement<br>CI = Classified, information as referred to in Commission Decision 2001/844/EC | PU |

## 1 Objectives of WP 4 – Scientific and Technological Exchanges

The combined scientific and technical expertise of the Consortium is a core asset of Laserlab-Europe, making it highly attractive for users and supporting a leading role of European science in photonics research. The objectives of this work package are i) to coordinate exchange on crucial scientific and technological issues of relevance for many partners, ii) to address the multidisciplinary applications of lasers and photonics technologies by bridging towards other ESFRI infrastructures and relevant networks, and iii) to pool know-how and good practice concerning essential operational issues such as security, laboratory management and data acquisition procedures.

The outcome of this scientific and technological networking will be increasingly unified efforts from all members of the Consortium, pushing forward laser science and technology in the European Community at large, as well as enhancing strong links with related networks and infrastructures such as ELI, Synchrotrons, FELs and life science networks.

## 2 Objectives

The purpose of Joint JRA meetings is to foster collaboration amongst the partners participating in the individual Joint Research Activities within Laserlab-Europe, providing a platform for sharing knowledge and experience as well as stimulating further network research activities in the context of JRAs. Joint JRA meetings represent an efficient means to induce a leverage effect on the knowledge and know-how created amongst the individual JRAs, to spread the knowledge throughout the entire Laserlab-Europe community and to create cross-fertilization effects.

## 3 Work description

The second Joint JRA meeting has been organised at LENS (European Laboratory for Non-linear Spectroscopy) in Florence, Italy, from 9 to 10 October 2019, followed by the public Laserlab-Europe conference on 11 October. The format of the meeting was prepared by the JRA board, consisting of the JRA coordinators and the chair person.

The number of participants in the Joint JRA meeting was about 80 belonging to all Laserlab-Europe partners involved in the JRAs. The participants very much appreciated the opportunity to learn about achievements in all four JRAs, and some expressed their wish to extend similar meetings in the future for another day in order to have more time for discussion and interaction.

Group picture on the campus of Polo Scientifico, Sesto Fiorentino (Florence)

In the following, a brief report on the Joint JRA Meeting sessions is given:

***October 9th***

The purpose of this first day meeting is to allow for the presentation of scientific achievements since the last individual JRA meetings. The JRAs were grouped in two sessions running in parallel, one for *ILAT-LEPP* and one for *PHOTMAT-BIOAP*P, which present commonalities in terms of complementing activities and fields of interest. At the end of each session a discussion on internal organisational issues in view of the preparation of the final deliverables and reports took place.

***PHOTMAT-BIOAPP Session***

| ***Title*** | ***Presenter*** | ***Reference Institution*** | ***JRA*** |
|---|---|---|---|
| *Femtosecond X-Ray Diffraction* | *Amélie Ferré* | *LP3* | *PHOTMAT* |
| *“MID-IR sources for photoionization experiment* | *Salvatore Stagira* | *POLIMI* | *PHOTMAT* |
| *Soft X-ray bioimaging at nanometer scale and patterning of polymer surfaces with EUV photons for bio-compatibility control* | *Henrik Fiedorowicz* | *MUT* | *PHOTMAT* |
| *Ultrafast Magneto-optical Sensing* | *Charlotte Sanders* | *CLF* | *PHOTMAT* |
| *Femtosecond electron diffraction* | *Luke Maidment* | *ICFO* | *PHOTMAT* |
| *Plasmonic sensors* | *Aleksejs Lihacovs* | *UL* | *PHOTMAT* |
| *Light-sheet microscopy* | *Ludovico Silvestri* | *LENS* | *BIOAPP* |
| *Bringing multimodal microscopies to the clinic* | *Freek Ariese* | *LLAMS* | *BIOAPP* |
| *Environmental sensing using cellular autofluorescence* | *Alzbeta M. Chorvatova* | *ILC* | *BIOAPP* |
| *Progress in spontaneous and coherent Raman imaging for tissue diagnostics* | *Christoph Krafft* | *IPHT* | *BIOAPP* |
| *Lasers, materials and beauty: how photoacoustic waves can make us look better* | *Luis Arnaut* | *UC* | *BIOAPP* |

***ILAT-LEPP Session***

| ***Title*** | ***Presenter*** | ***Reference Institution*** | ***JRA*** |
|---|---|---|---|
| *Summary laser material development* | *Laurent Lamaignere* | *CESTA* | *ILAT* |
| *Accurate high rep-rate CEP measurements* | *Adam Borzsonyi* | *USZ* | *ILAT* |
| *High power MID-IR fiber lasers* | *Luke Maidment* | *ICFO* | *ILAT* |
| *Next generation coherent X-ray sources* | *David Garzella* | *LIDYL* | *ILAT* |

| | | | |
|---|---|---|---|
| *New algorithm in PIC code for a better modelling of the transverse properties of the wakefield accelerated beam* | *Xavier Davoine* | *CEA* | *LEPP* |
| *20GW attosecond XUV beam-line* | *Dimitris Charalambidis* | *FORTH* | *LEPP* |
| *Imaging and spectroscopy in the soft x-ray* | *Holger Stiel* | *MBI* | *LEPP* |
| *Radiobiology with the fast fractionation effect* | *Alessandro Flacco* | *LOA* | *LEPP* |
| *An action of ionizing radiation on (bio)molecular systems at high dose* | *Ludek Vysin* | *IP-CAS* | *LEPP* |
| *Preparation for laser-based proton beam irradiation in vivo zebrafish model* | *Rita Emilia Szabo & Tunde Tokes* | *USZ* | *LEPP* |
| *Proton detector based on scintillators for High rep rate at Dresden* | *Luca Volpe* | *CLPU* | *LEPP* |

***October 10th (+extension to October 11th)***

The meeting on the second day (with an extension to October 11th) consisted in a plenary session comprising presentations of highlights of each of the four JRAs, given by the respective task leaders. This joint plenary session was open to all JRA participants, helping to enhance exchange about scientific advances among the scientists involved in the project. In addition, this plenary session was open to participants in the Laserlab-Europe conference on the following day. Two additional selected highlights were given during the Laserlab-Europe conference.

Programme of the presentations in the plenary session:

| ***Title*** | ***Presenter*** | ***Participating Institutions*** | ***JRA*** |
|---|---|---|---|
| *Development of a new diagnostic technique based on time-domain DCS and/or development and characterisation of tissue-mimicking phantoms* | *Cosimo D'Andrea* | *POLIMI,IFCO* | *BIOAPP* |
| *Advanced Attosecond Working Stations for Material Science Studies* | *Philippe Martin* | *CEA-LIDYL, LOA, ISMO, FORTH, MPG-MPQ* | *PHOTMAT* |
| *Advances of ultrafast lasers' employment for the highly-efficient fabrication of mesoscale structures combining individual micro-/nano features with overall macro-dimensions out of various biomaterials* | *Mangirdas Malinauskas* | *VULRC, FORTH* | *BIOAPP* |
| *Advanced Time resolved non-linear spectroscopy* | *Christian Manzoni* | *POLIMI, LU, LLAMS* | *PHOTMAT* |
| *Advances in Spectroscopic Analytical Capability* | *Freek Ariese* | *LLAMS* | *PHOTMAT* |

| | | | |
|---|---|---|---|
| *Targetry* | *Dino Jaroszynski* | *MUT, STRATH* | *LEPP* |
| *Preparing laser accelerated proton beams for dose controlled irradiation studies* | *Ulrich Schramm* | *HZDR, LULI, LOA* | *LEPP* |
| *Laser beams control and combination* | *Jean-Christophe Chanteloup,* | *LULI, STFC* | *ILAT* |
| *High repetition rate CEP and spatio-temporal pulse characterization"* | *Cord Arnold* | *LLC, USZ* | *ILAT* |
| *MID-IR laser development* | *Federico Furch* | *MBI, ICFO, MPG* | *ILAT* |
| ***October 11th extension*** | | | |
| *Lab based X-ray sources and instrumentation for imaging and spectroscopy* | *Holger Stiel* | *MBI, CELIA, LOA, LLAMS* | *LEEP* |
| *Multimodal microscopy and spectroscopy for advanced diagnostics of bladder tumour* | *Riccardo Cicchi* | *LENS* | *BIOAPP* |

Summary presentations for the highlights can be found in the Annex.

## 4 Conclusions and Outlook

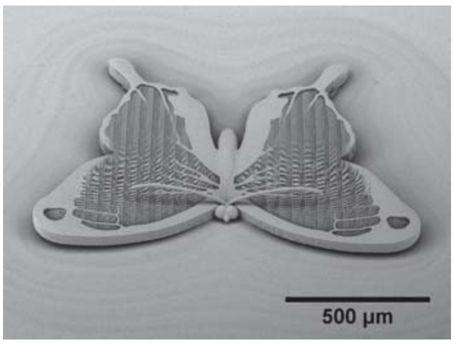
Although the single JRA meetings are not to be abandoned due to a more in-depth overview of the work and participation in the discussions, it was acknowledged that the "joint format" is important for stimulating collaborations between the communities. The JRA meetings scheduled in Laserlab-Europe over the period of the present contract are indeed fulfilling this need, being planned in an individual and joint format in alternating years. The experience acquired in the organization of the present Joint JRA meeting will be useful for introducing some improvements in the format in view of future similar meetings.

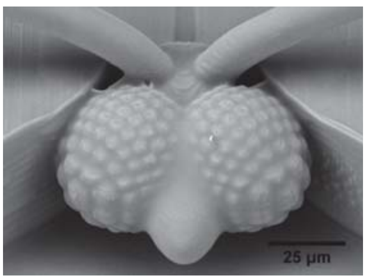
# JRA Highlights
# Joint JRA Meeting, Florence 9-10 Oct. 2019

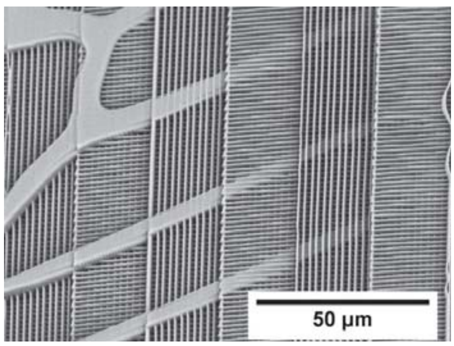
1. *Meso-Scale (Multi-Scale) Laser 3D Printing of Biomaterials*
2. *Multimodal spectroscopy for tissue diagnostics*
3. *Stimulated Raman scattering (SRS) microscopy*
4. *Time-Domain Diffuse Correlation Spectroscopy*
5. *Development of sources and instrumentation for X-ray spectroscopy & imaging*
6. *Two-dimensional Electronic Spectroscopy*
7. *Coherent Beam Combination update and Fast Pointing Beam Stabilisation*
8. *Thin-disc and volume laser based mid-IR sources*
9. *High-rep. rate, single-shot, measurement of the carrier-to-envelope offset phase*
10. *Advanced Attosecond Working Stations for Material Science Studies*
11. *Preparing laser accelerated proton beams for dose controlled irradiation studies*
12. *Targetry*

Vilnius University

## *1A - Meso-Scale (Multi-Scale) Laser 3D Printing of Biomaterials*



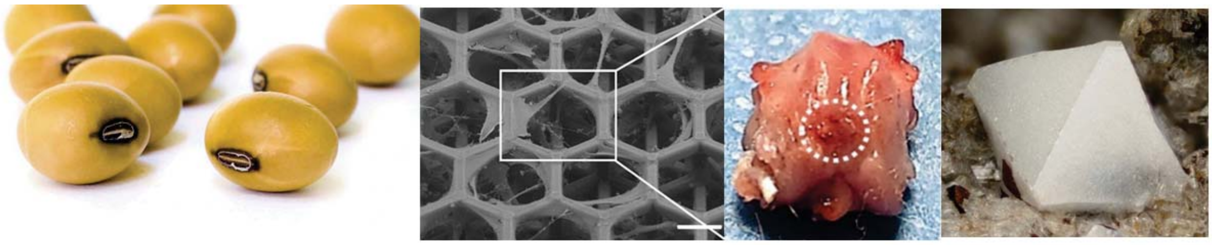




**A problem associated with direct laser writing 3D lithography (two-photon polymerization) is the <u>limited throughput</u>, an <u>inevitable stitching/overall object size</u> and a <u>choice of materials</u>.**

# 1B - Meso-Scale Laser 3D Printing of Bio-Materials

*from natural biodegradable/biocompatible to synthetic tunable properties composites towards pure inorganics*

**Proteins – Biopolymers – Hydrogels – Acrylates – Epoxies-Organic-Inorganic Hybrids**



Scientific papers proposing the solution and acknowledging LL JRA BIOAPP:

- L. Jonušauskas, D. Gailevičius, S. Rekštytė, T. Baldacchini, S. Juodkazis, M. Malinauskas, Mesoscale Laser 3D Printing, Opt. Express 27(11), 15205-15221 (2019); https://doi.org/10.1364/OE.27.015205, OSA [IF-3.356].
- A. Butkutė, L. Čekanavičius, G. Rimšelis, D. Gailevičius, V. Mizeikis, A. Melninkaitis, T. Baldacchini, L. Jonušauskas, M. Malinauskas, Optical Damage Thresholds of Microstructures Made by Laser 3D Nanolithography, in PrePrints / under review (2019).

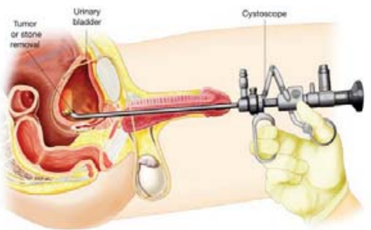
femtika

Laserlab Europe

# 2A - Multimodal spectroscopy for tissue diagnostics

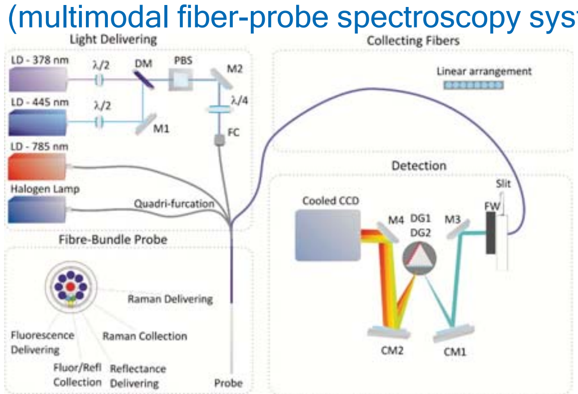
Lens European Laboratory for Non-Linear Spectroscopy

## TURBT (Trans-urethral resection of bladder tumour)




- To endoscopically diagnose bladder tumour as well as to perfrom tumour grading and staging
- Biopsy (small) + sectioning + staining
- Difficulties for the pathologists in:
  - Orienting the samples
  - Identify slicing direction
  - <u>Difficult diagnosis</u>

## Experimental setup (multimodal fiber-probe spectroscopy system)



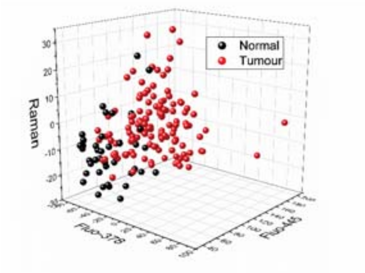

- Laser diodes @378 nm & @445 nm
- Halogen Lamp
- Laser diode @785 nm
- Quadrifuracted probe (EMVision LLC)
- Spectrograph (grating 600 lines/mm)
- Cooled CCD camera (Horiba Syncerity)

Probe tip

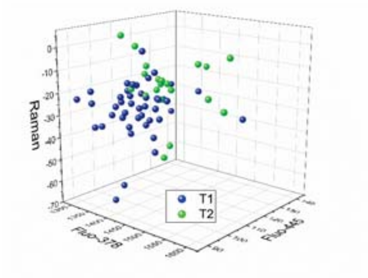
R. Cicchi, A. Cosci, S. Rossari, D. Kapsokalyvas, E. Baria, V. Maio, D. Massi, V. De Giorgi, N. Pimpinelli, and F.S. Pavone, J Biophoton **7**, 86-95 (2014)

# 2B - Bladder tumor staging

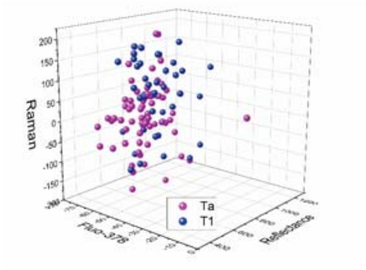
Normal vs Tumour



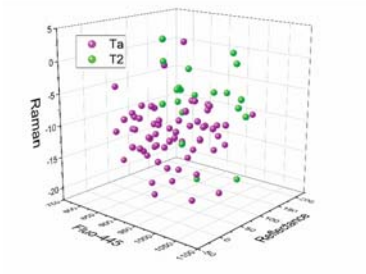

T1 vs T2




T1 vs Ta




T2 vs Ta

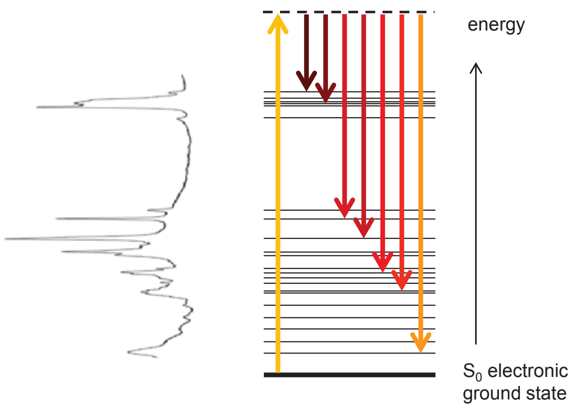



| | Specificity (%) | Sensitivity (%) | AUC (%) |
|---|---|---|---|
| normal vs tumour | 90 | 74 | 91 |
| T1 vs T2 | 80 | 85 | 85 |
| T1 vs Ta | 73 | 71 | 75 |
| T2 vs Ta | 80 | 80 | 86 |


E. Baria, S. Morselli, S. Anand, R. Fantechi, G. Nesi, M. Gacci, M. Carini, S. Serni, R. Cicchi, and F.S. Pavone, J Biophoton **12**, (2019) DOI: 10.1002/jbio.201900087

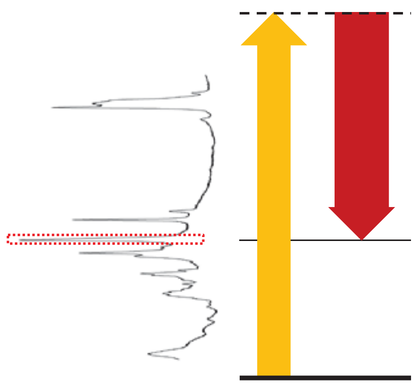

# 3A - Stimulated Raman scattering (SRS) microscopy

Conventional Raman scattering




Complete vibrational spectra, but slow!

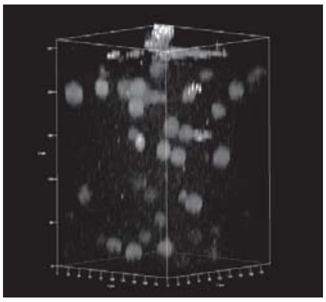
Stimulated Raman scattering



Requires two pulsed lasers; much faster for mapping

# 3B - Recent SRS developments

Long-wavelength SRS (using the OPO idler output in combination with 1064 nm pump beam) enables deeper imaging

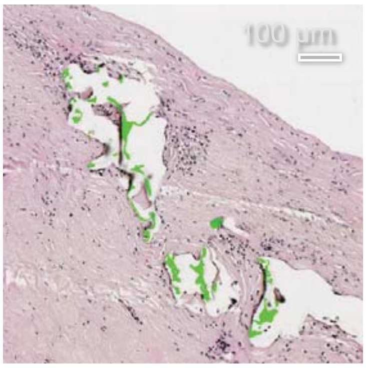


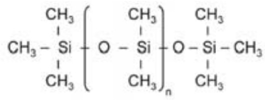
*3D distribution of 15-µm polyethylene microspheres embedded in a silicone rubber matrix, down to 250 µm*

Environmental microplastics

*Hyperspectral SRS at 6 wavenumbers was developed to detect and identify microplastic particles (down to 10 µm) in harbour sediment*

*We found a total of 12 000 particles/kg sediment*



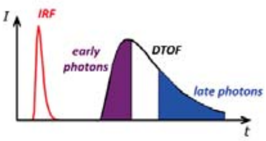
Polydimethylsiloxane (PDMS)

*Leaking silicone gel from breast implants is a major problem, but it is invisible to the pathologist*

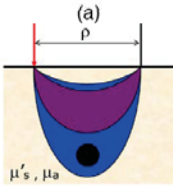
*Silicone can be detected by SRS microscopy at 2905 cm$^{-1}$ (C-H stretch vibration) and then overlaid (in green) on a standard H&E image.*



# 4A - JOINT POLIMI - ICFO LABORATORY ON Time-Domain Diffuse Correlation Spectroscopy (DCS)




(a)




(b)

POLITECNICO MILANO 1863

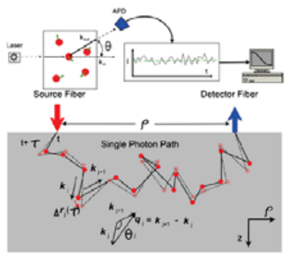
**Time-Domain Diffuse Optics**

- Optical properties
- Time encodes space

ICFO MEDOPT Medical Optics Group

**Diffuse Correlation Spectroscopy**

- Relative Blood flow




**POLIMI + ICFO**

**Time-Domain DCS**

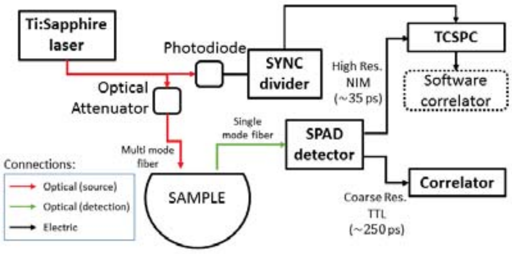
- 4 papers + 3 in progress
- 10 researchers involved

- Depth-resolved (cm) blood flow
- Absolute quantitation

**Joint POLIMI+ICFO distributed laboratory**
**Long-Term perspective: Foundation of TD-DCS towards clinical translations**

## 4B

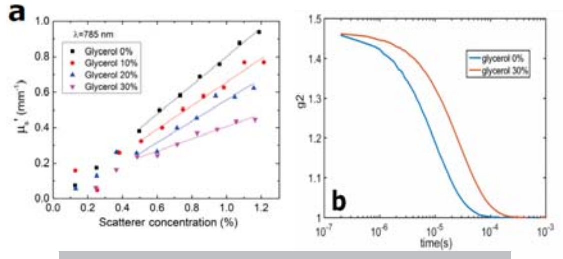
### Action 1 – new workstation @POLIMI




M.Pagliazzi *et al.,* Biomed. Opt. Express **8** (2017)

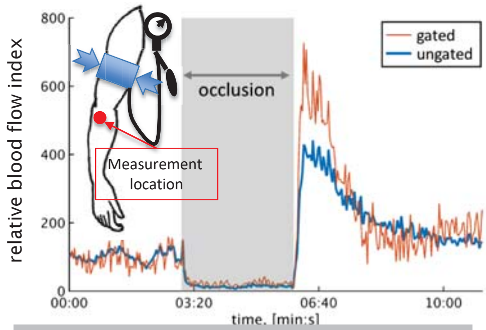
### Action 2 – design of reference tissue phantoms

Lipofundin (**scattering**) + Ink (**absorption**)
+ Glycerol (**viscosity**)



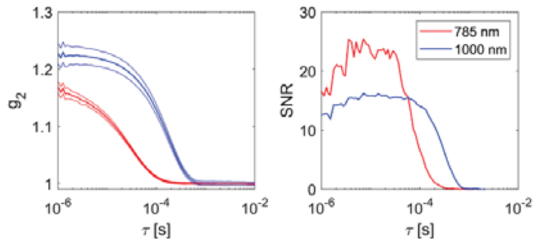

L.Cortese et al., Biomed. Opt. Expr. (2018)

### Action 3 – first time-gated in vivo data




M. Pagliazzi et al., Opt.Lett. (2018)

### Action 4 – in vivo measurements >1000 mm

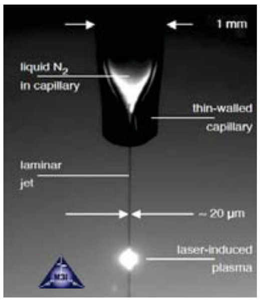


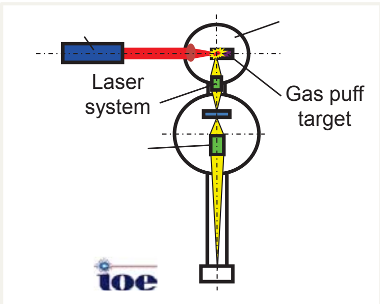

- Higher amplitude ($\beta$) and slower decay of $g_2$
- SNR shifted to higher $\tau \rightarrow$ chance of *parallel detection*

L.Colombo et al., in preparation (2019)

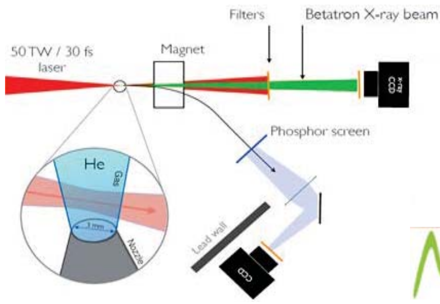
# 5A - Development of sources and instrumentation for X-ray spectroscopy & imaging

## Laser-produced plasma X-ray sources (LPP)

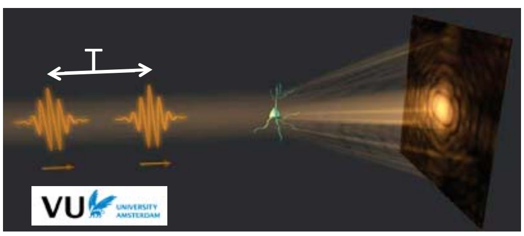


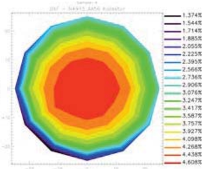

## Betatron radiation

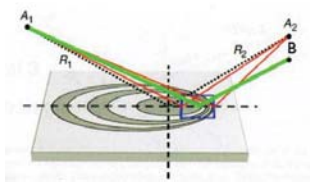



## High Harmonic Generation (HHG)



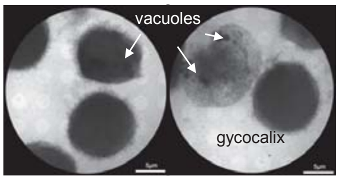
## Optics, spectrometers, detectors





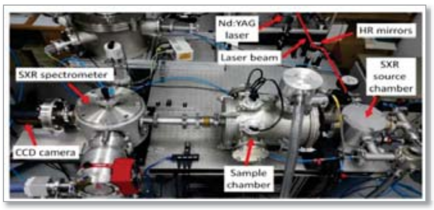

# 5B - Applications

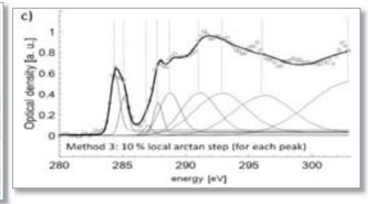
## X-ray microcopy in the lab




*Soft X-ray microscopy of cryo-fixated THP-1 Cells. Inner structures as well as the glycocalix are clearly visible.*

## Soft X-ray spectroscopy in the lab



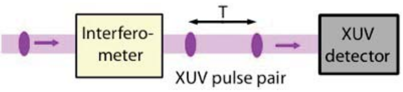



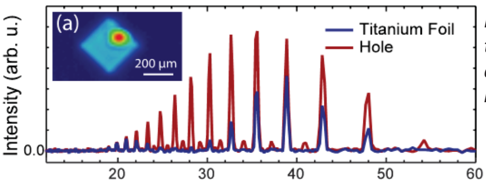

*Experimental setup*

*NEXAFS spectrum for a 1 µm thick PET sample*

*Wachulak et al. Optics Express 26, 8260 (2018)*

## Spatially resolved HHG spectroscopy

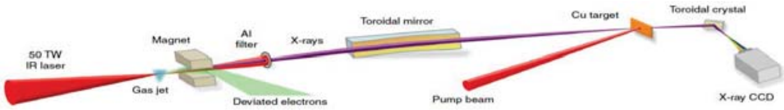



*Measurement of transmission through a $Ti/Si_3N_4$ film 17-55 nm range.*

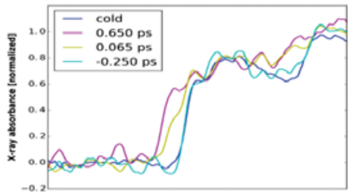
*Jansen et al., Optica **3**, 1122 (2016)*

## Warm dense matter investigated using betatron radiation



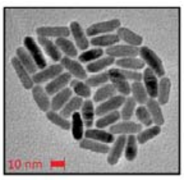

*Heating a copper foil with a temporal resolution better than 50 fs.*

*B. Mahieu et al., Nat. Comm. **9** 3276 (2018)*

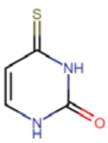



# 6A -Two-dimensional Electronic Spectroscopy

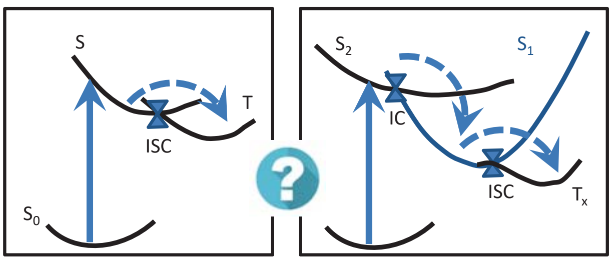
**Goal**: increase the availability of **2D spectroscopies to the users of Laserlab**, by developing a suite of different experimental techniques coupled to data visualization and analysis tools.




Characterization of relaxation times and paths in CdSe Nanorods:
**2D electronic spectroscopy** and **modeling**




Understanding ultrafast dynamics in nucleobasis:
**Ultrafast spectroscopy in the UV spectral range**



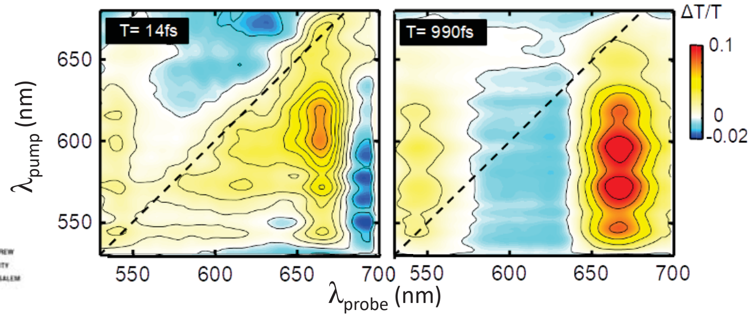
# 6B - Main achievements

## CDSE NANORODS

2DES + Global analysis:

- relaxation from *high energy excitons* to an *intermediate state*: **124-fs** time constant
- relaxation to the *lowest exciton*: **217-fs** time constant

*Collaboration with Prof. Uri Banin*

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## 4-THIOURACYL

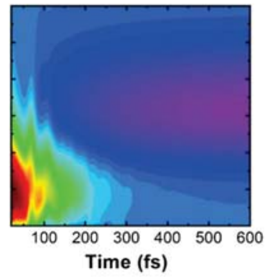
UV spectroscopy system:

- Sub-20 fs UV pulses at 270 and 330nm
- Evidence of an intermediate state mediating internal conversion

*Collaboration with Prof. M. Garavelli and Ivo van Stokkum*

Experimental

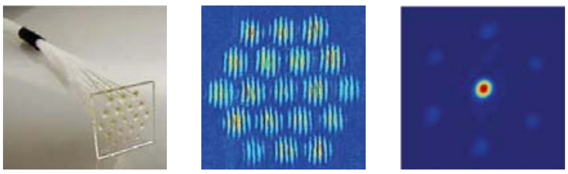
Simulated




R. Borrego-Varillas *et al.*, J. Am. Chem. Soc. **140**, 16087 (2018)

# 7A - LULI, France : Coherent Beam Combination update

- CBC demonstrated with 19 passive fibers in the femtosecond regime



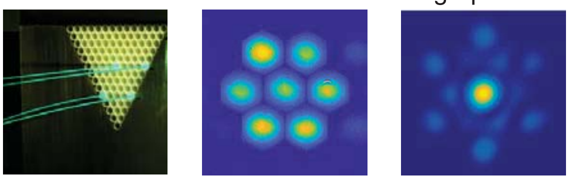
Laserlab Berlin spring 2017

- 49.5% combining efficiency
- 300 fs combined pulse
- λ/60 RMS phase stability

*J.Le Dortz et al., "Highly scalable femtosecond coherent beam combining demonstrated with 19 fibers", Opt. Lett. 42, 1887-1890 (2017)*

- First demonstration w/ 7 femtosecond high-power fiber amplifiers

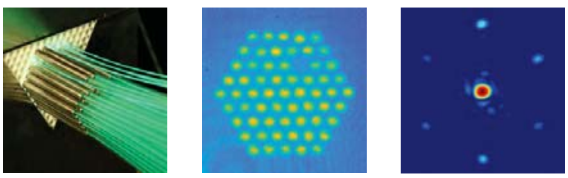
Laserlab Garching spring 2018



- 71 W @ 48% combining efficiency (55MHz) (46% @ B = 5 rad; 2 MHz)
- 216 fs combined pulse
- λ/55 RMS phase stability

*A.Heilmann et al., "Coherent beam combining of seven fiber chirped-pulse amplifiers using an interferometric phase measurement" Opt. Exp. 26, 31542-31553 (2018)*

- Scaling to 61 fibers

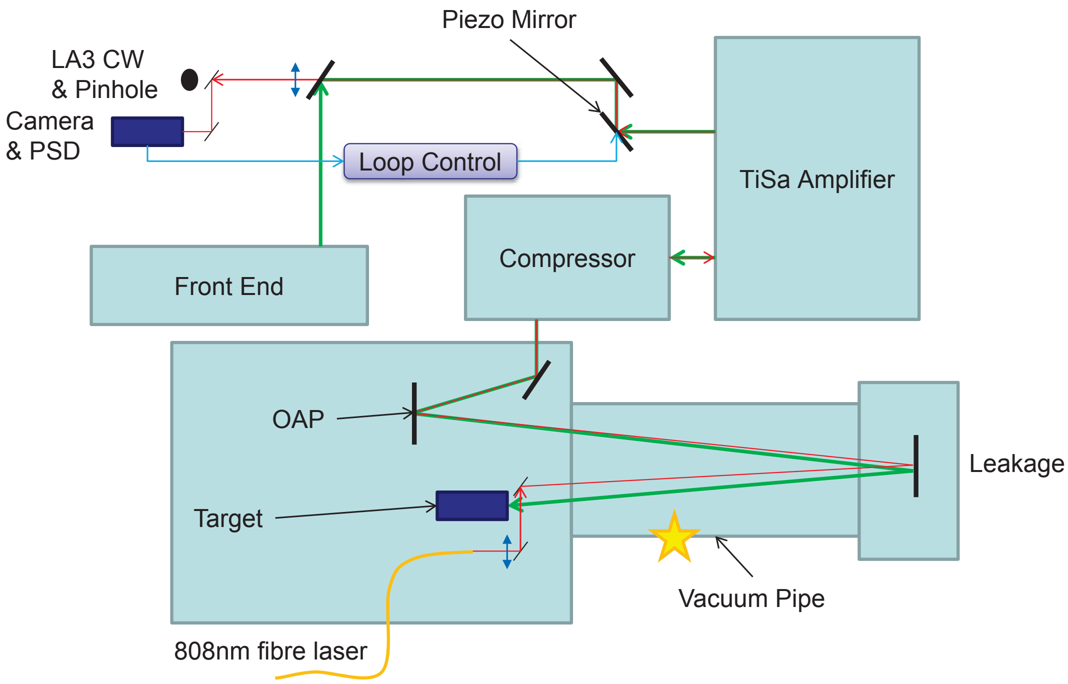


- 96 W @ 46% combining efficiency (55MHz)
- 221 fs combined pulse
- λ/100 RMS phase stability

Laserlab Florence Fall 2019

*I.Fsaifes et al., "Coherent Beam combining of 60 femtosecond fiber amplifiers« ,Invited, Feb 4th, Photonic West, SF, CA, USA*

## *7B - RAL, UK: Fast Pointing Beam Stabilisation on Gemini*




## 8A - Thin-disc and volume laser based mid-IR sources

Development of thin-disk and volume laser based pump lasers

- Moderate repetition rates up to a few kHz.
- High energy up to a few hundred mJ.

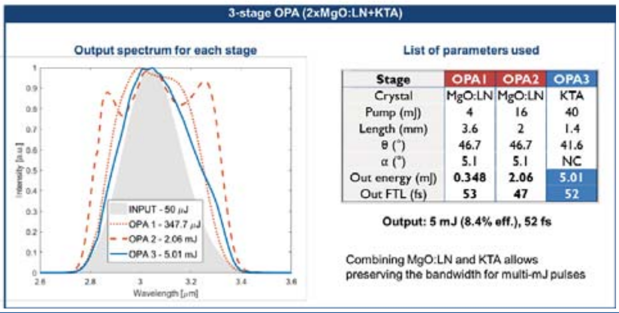
Implementation of pump lasers in OPCPAs

- Demonstrate the potential of the developed laser sources as pumps for OPCPA systems.
- Develop mid-IR sources in the 1.6-2.7 µm and 5-10 µm ranges.
- Applications in the study of ultra-fast phenomena

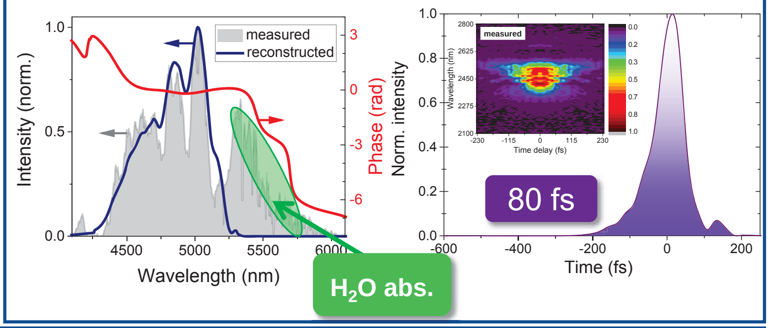
**Highlights from: MPQ, IST, FVB-MBI**

# 8B - Highlights: From pump development and OPCPA design to applications with mid-IR OPCPAs

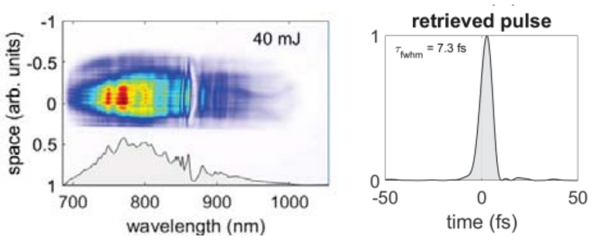
Pump for OPCPA: Development of 100 mJ, 1030 nm Yb-based CPA completed. OPCPA design: KTA/MgO:LN based 5 mJ OPCPA at 3 µm.



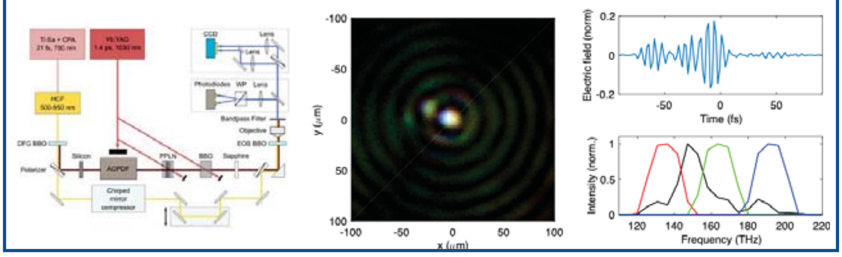

Pump for OPCPA: Development of 1 kHz, 55 mJ, 2 µm Ho-YLF CPA ZGP-based OPCPA : 3.2 mJ, 80 fs at 5 µm.




Pump for OPCPA: Development of 100 Hz, 300 mJ, 1030 nm Yb:YAG thin-disc amplifier. OPCPA : 40 mJ, < 8 fs at 800 nm.




2 µm OPCPA pumped by Yb:YAG amplifier at 1030 nm. Application: spatially resolved electro-optical sampling of beam focused with metasurface axicon.

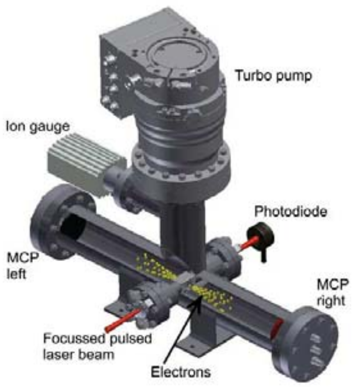



# 9A - High-repetition rate, single-shot, measurement of the Carrier-to-envelope (CEP) offset phase

LUND UNIVERSITY

**Two main approaches for CEP measurements of amplified laser pulses exist.**

Stereo Above-Threshold Ionization (ATI)

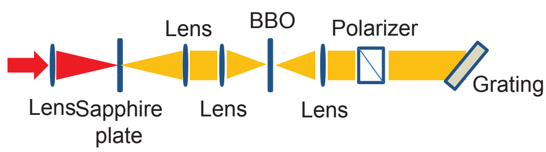



- Needs short pulses to be conclusive
- Complicated setup and analysis
- Absolute measurement

Max-Born-Institut

D. Hoff *et al*., Opt. Lett. **43**, 3850 (2018)

f-2f interferometry

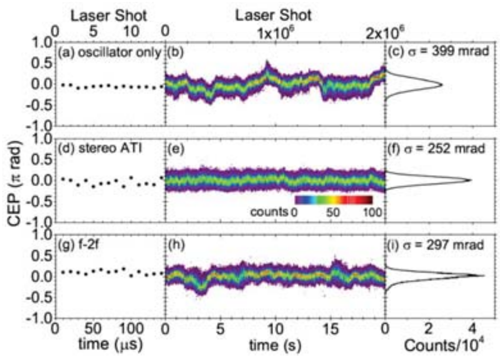



- Simple setup and analysis
- Octave-spanning spectrum required
- Indirect measurement
- Pulse energy to CEP coupling

200 kHz line camera as detector

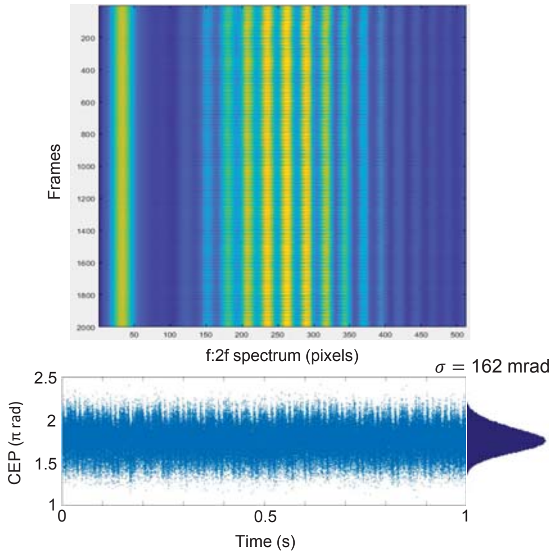
# 9B - Single-shot, full repetition rate CEP measurements performed in Lund and at MBI

### MBI OPCPA measured with Stereo ATI at 100 KHz




D. Hoff *et al.*, Opt. Lett. **43**, 3850 (2018)

### Lund OPCPA measured with f:2f spectrometry at 200 kHz




# *10A - Advanced Attosecond Working Stations for Material Science Studies*

5 labs were involved

**Laser Interactions and Dynamics Laboratory**

**Institut des Sciences Moléculaires d'Orsay**

**Institute of Electronic Structure & Laser** FO.R.T.H. - I.E.S.L.

**Technical University of Munich**

**Laboratoire d'Optique Appliquée**

## 10B - Main Realisations

**Finalized Plateforms**

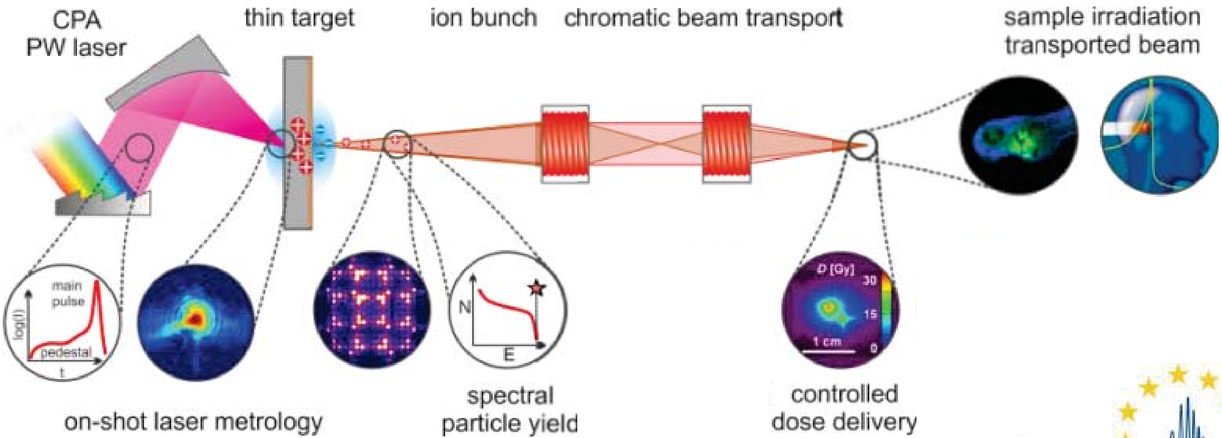
- **LIDYL : ATTOLAB completion : Two high rep-rate XUV-IR beamlines : 2 mJ@10Hz & 15 mJ&1KHz, 23 fs, CEP**
- **ISMO : COLTRIM End Station**
- **FORTH : Long focal High Orde Harmonics beam line**
- **TMU : Attosecond high photon flux beamline (moved from MPQ)**
- **LOA : TW-class, few-cycle pulse laser system at 1kHz**

**Scientific Breakthrough (number of publication under preparation)**

- **LIDYL : Revealing attoecond photoionization dynamics in Argon Cooper minimas**
- **ISMO : Angle resolved RABBIT: XUV+IR ionization of Ar and Ne**
- **FORTH : more than 0.7 ·$10^{14}$ photons/pulse in XUV through HHG using a double jet**
  *A. Nayak et al.,Multiple ionization of argon via multi-XUV-photon absorption induced by 20-GW high-order harmonic laser pulses, Phys. Rev. A **98**, 023426*
- **TMU : First absolute ionisation time from Electrons in iodine sub-monolayers deposited on a tungsten substrate :** *Ossiander, M. et al. Absolute timing of the photoelectric effect. Nature **561,** 374–377 (2018)*
- **LOA : CEP effects in High Charge MeV electron beams**

## 11A - Preparing laser accelerated proton beams for dose controlled irradiation studies

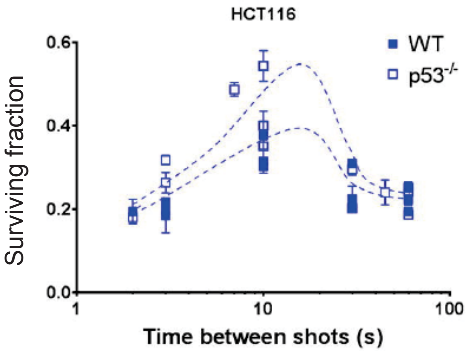
- *Demonstrate mature performance of a laser proton accelerator beyond 50 MeV*
- *Demonstrate controlled dose delivery (and metrology / dosimetry)*
- *Explore new regimes with unique source characteristics (dose rate effects)*

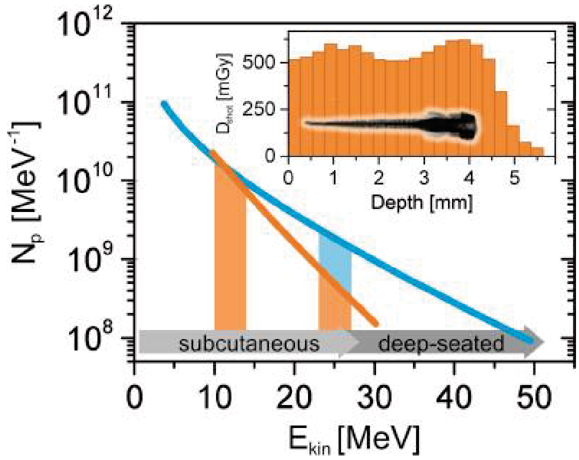


## 11B - Preparing laser accelerated proton beams for dose controlled irradiation studies

- Spatial and temporal pulse control
- Tailored plasma target conditions
- Complete online (on-shot) metrology
- Pulsed beam matching transport
- And pulsed beam dosimetry

*Example of dose rate dependent tumor cell response*



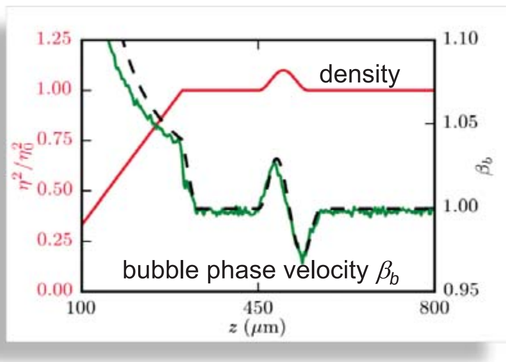




*Example of energy increase by controlled target pre-expansion*



# 12A -Targetry

- Targets come in many forms: gas, liquid, solid, vacuum
- LASERLAB covers all bases
- Opportunities to collaborate – targets are used in almost all experiments – one group making a target for an experiment = joint activity
- One example of a joint activity: collaboration to develop a gas jet with an ultrashort density variation



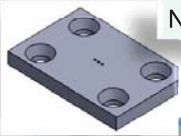

M.P. Tooley et al., PRL 2017

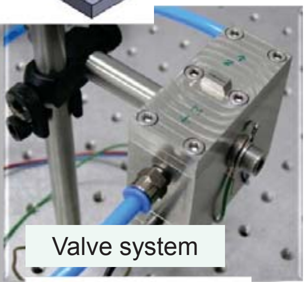
# 12B - MUT – STRATH collaboration: Elongated gas puff target with a profiled gas density profile for attosecond bunch injection

## Motivation and aim:

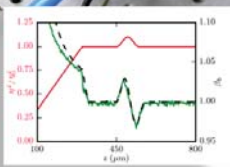
formation of target with a profiled gas density for laser-plasma attosecond electron bunch injection

Nozzle



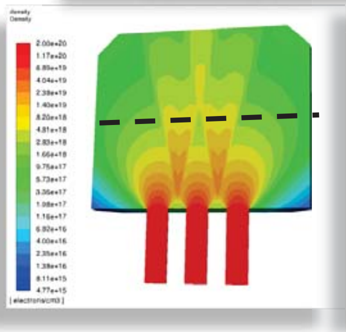


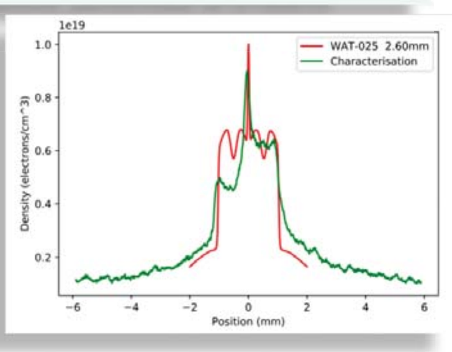
Valve system



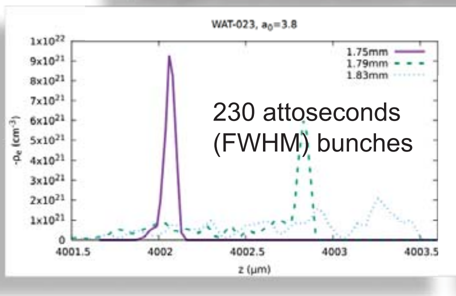
M.P. Tooley et al., PRL 2017

## Numerical simulations performed at STRATH






## Target characterization measurements at MUT




EUV shadograph