fs-TALIF in RAID
ENR-TEC SB 2024

marcelo.baquero@epfl.ch

Marcelo Baquero-Ruiz, 5 February 2025

Swiss
Plasma
Center

Outline

marcelo.baquero@epfl.ch

1. Overview
2. Status of tasks
3. Issues
4. Planning for 2025

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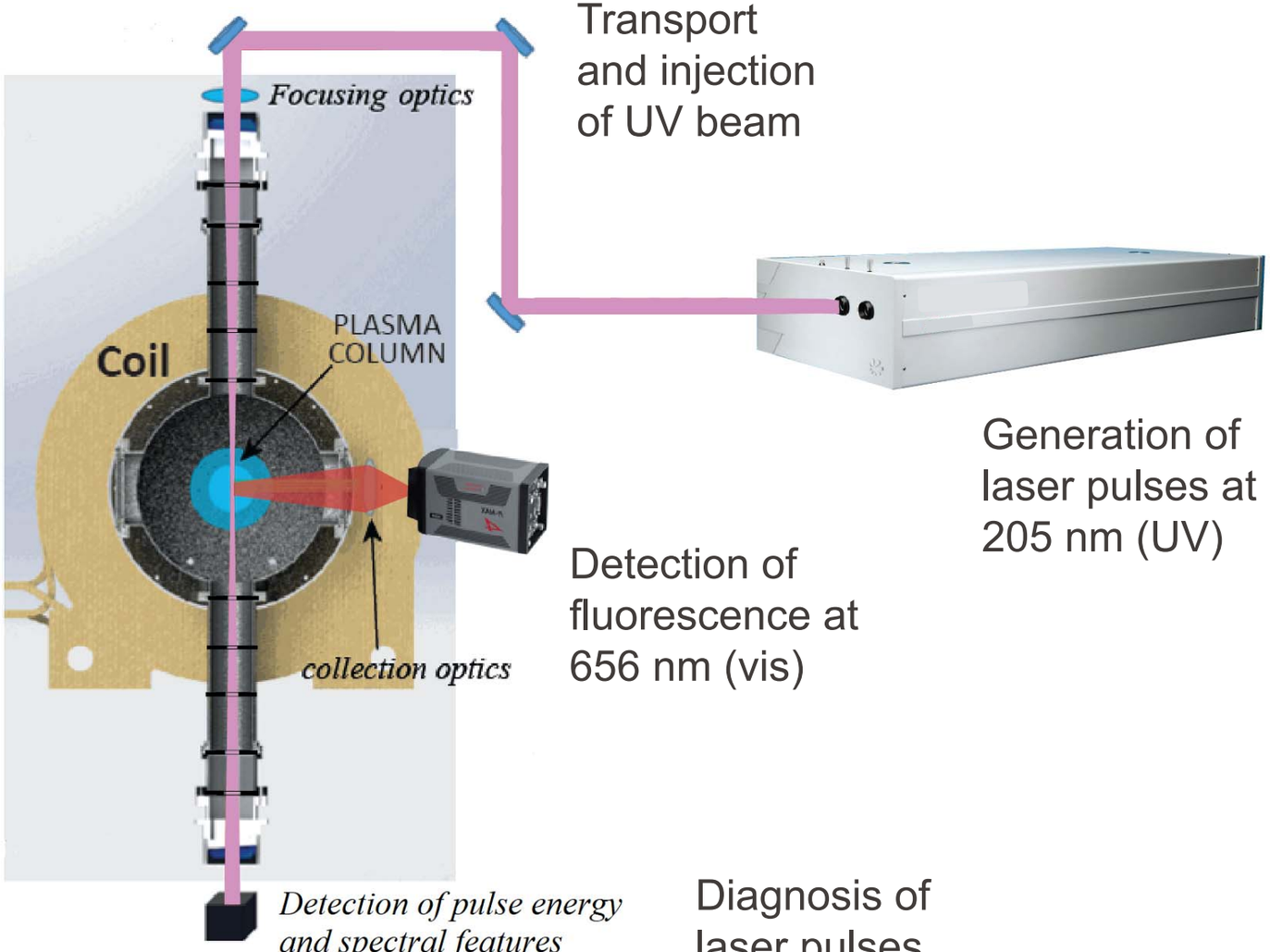
Overview: Objective

*Obtain **single laser-pulse** measurements of H densities in a dense hydrogen plasma using fs-TALIF.*

We will provide an assessment on the feasibility of this method.

marcelo.baquero@epfl.ch

Overview: Schematic of project



Transport
and injection
of UV beam

Generation of
laser pulses at
205 nm (UV)

Detection of
fluorescence at
656 nm (vis)

Diagnosis of
laser pulses

marcelo.baquero@epfl.ch

Overview: Proposed tasks (all)

T1	• Build fourth-harmonic generator (FHG) for fs laser at LACUS. • Upgrade Astrella system to deliver required fs pulses at ≈820 nm. • Characterize energy and spectrum of 205 nm (UV) pulses – notably their stability.
T2	• Set up fluorescence detection system.
T3	• Design and build beam-path for fs UV pulses. • Build pulse compressor to compensate for dispersion of pulses during propagation and injection.
T4	• Test calibration method using Kr gas with laser tuned for H.
T5	• Understand the theory of fs laser absorption. • Study n=3 substate mixing.
Texp	• Experiments in RAID (fs TALIF in H plasmas).

marcelo.baquero@epfl.ch

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Status of 2024 Tasks

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Statement of progress (as of Feb. 2025)

All major milestones proposed for 2024 were reached.

fs-TALIF project is on track for completion within the originally proposed time frame.

Some obstacles have been encountered that do not have (for the moment) a major impact on the schedule.

marcelo.baquero@epfl.ch

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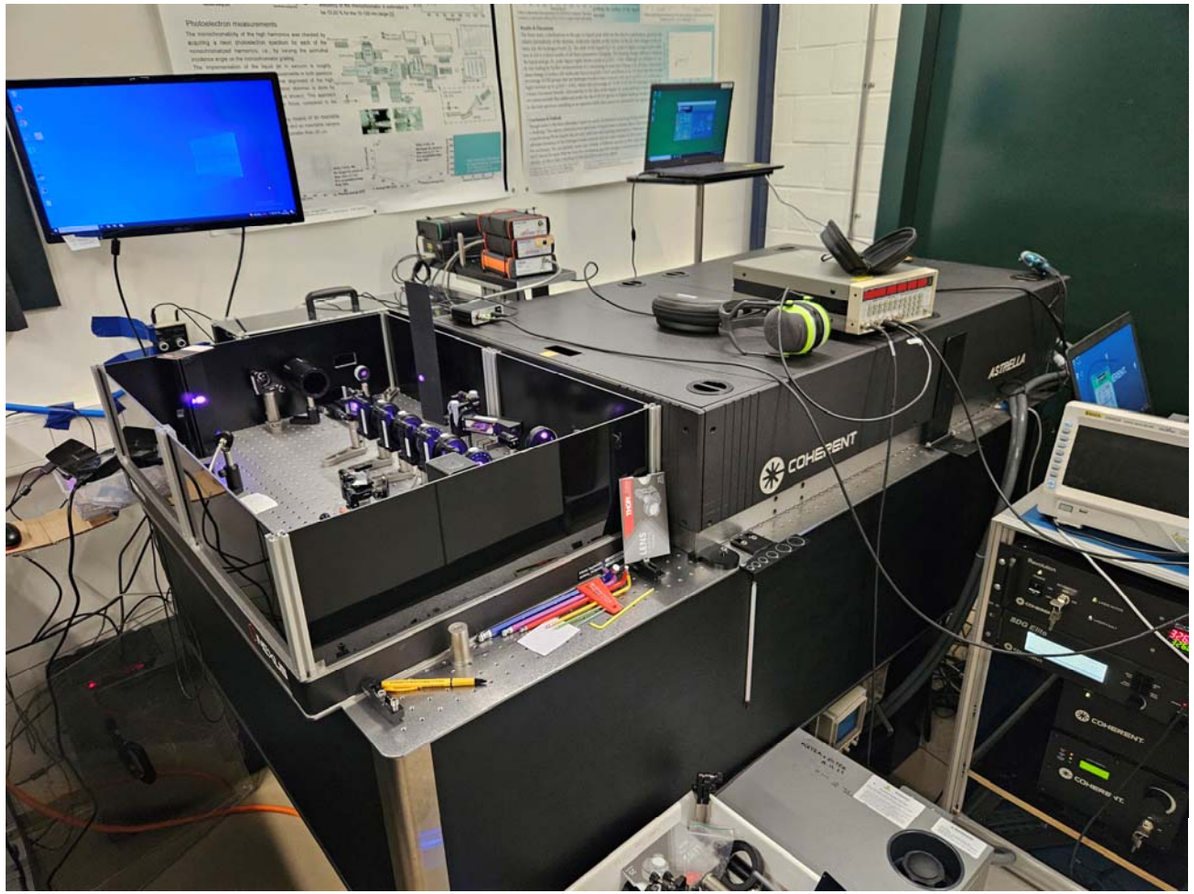
T1: M1 and M4

FHG module and Astrella upgrade



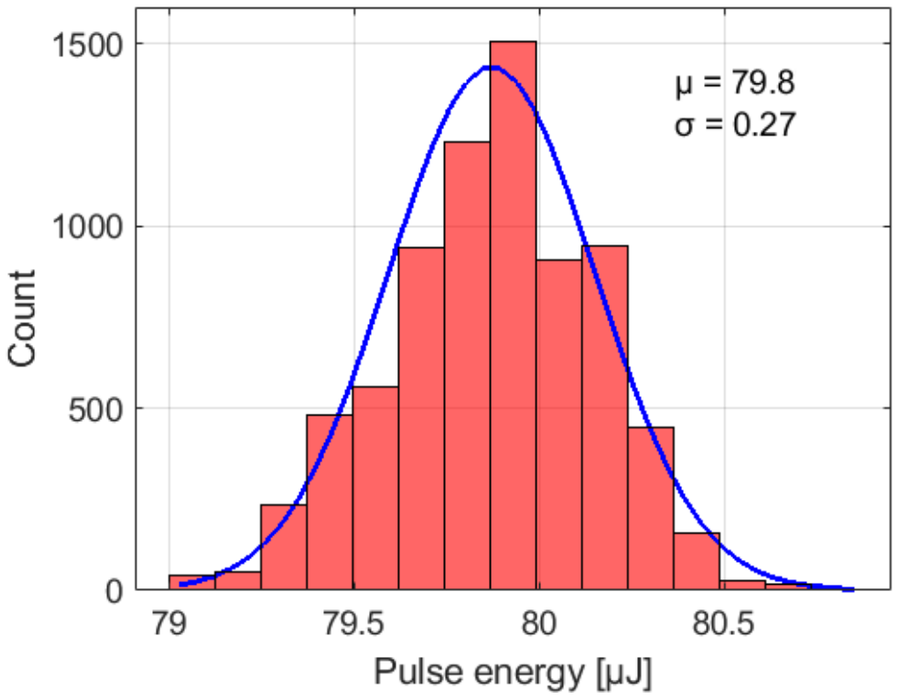
- FHG module is operational.
- Conversion efficiency (≈1.1%) slightly lower than target (2%) but sufficient for experiments.
- Astrella system upgraded to 1kHz rep-rate, 7 mJ per pulse at 820 nm, pulse duration < 100 fs.

marcelo.baquero@epfl.ch

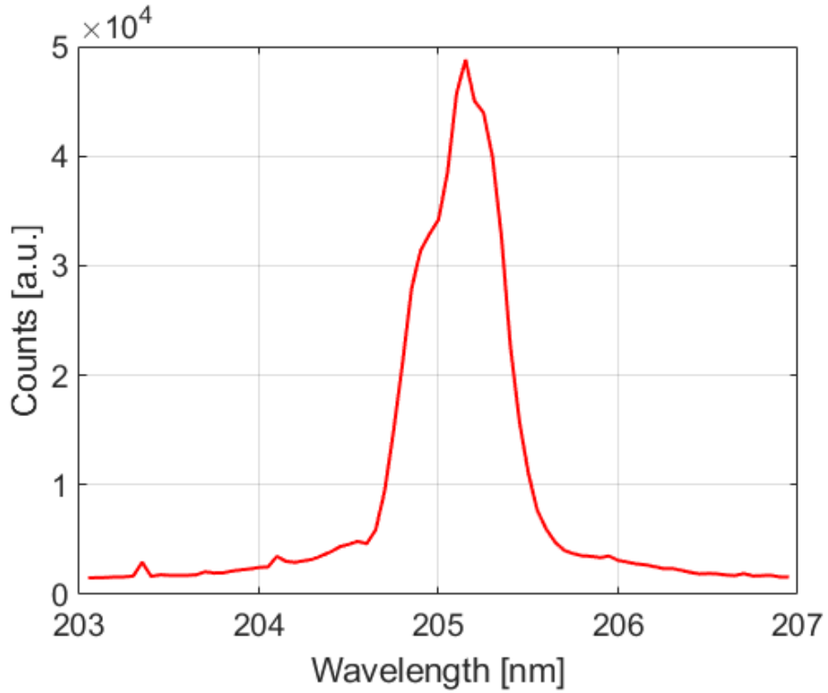
T1: M3

Characterization of UV fs pulses

- Stable UV pulse energies of ≈ 80µJ



- Stable spectral features and FWHM bandwidth ≈ 0.5nm



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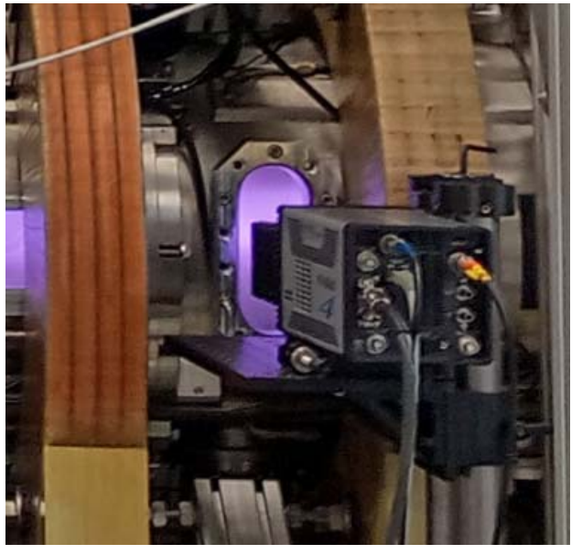
T2: M7

Fluorescence detection



- System based on imaging optics, optical filtering and a very short (down to ~1ns) gating time ICCD camera.

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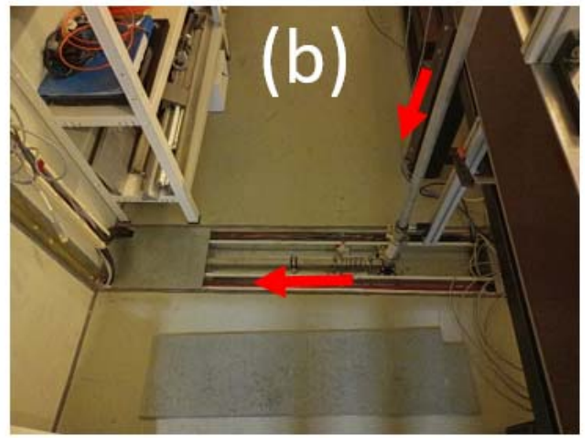
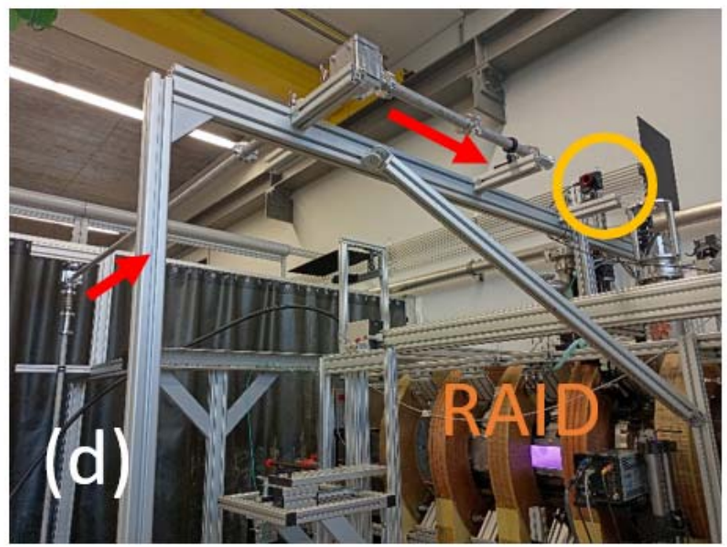
T3: M5 and M6

Design and construction of beam-path





marcelo.baquero@epfl.ch

T3: Pulse compressor

- Optical system composed of two prisms to change laser pulse time envelope so that any dispersion along the beampath is pre-compensated.
- Prisms have been procured but have not been installed nor tested yet.

marcelo.baquero@epfl.ch

T5: M2

Theoretical studies of laser pulse absorption

- Extremely important to determine validity of models to interpret TALIF data.
- Discussion at FLTPD-2024 conference and recent works show that standard assumptions may not be valid in the fs regime.
- Exploring feasibility of using simulations of H subject to intense fs fields (possible collaborations).

marcelo.baquero@epfl.ch

T5: M8

Theoretical studies of n=3 substate mixing

marcelo.baquero@epfl.ch

- Possible effect of ion collisions.
- Ongoing studies to check applicability of models to RAID plasma conditions.

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Issues

1. Astrella system is currently **not** operational.
   - Laser stopped in December due to a defective component.
   - Servicing is scheduled for February. Repair of component should last ~1 month.
     - Transport from LACUS to SPC is planned during that time to reduce impact on project schedule.

2. Refractive optics (windows and lenses) may absorb a significant fraction (up to ~10%) of the laser power for the large intensities sought in this project.
   - Characterization of absorption will resume when Astrella is available.

3. Heating of RAID chamber may affect (slightly) alignment of final parts of beampath.

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Tasks for 2025

T5	• Continue studies on theory of fs laser absorption. • Continue studies on n=3 substate mixing.	All 2025
–	• Transport Astrella and FHG from LACUS to SPC	March
T3	• Install pulse compressor at output of FHG.	April
T4	• Test calibration method using Kr gas with laser tuned for H. (Although originally planned at LACUS, this will be done at SPC.)	April
–	• Inject UV laser into beampath and perform alignment. • Characterize fs pulses arriving in RAID	May
Texp	• First experiments in RAID (fs TALIF in H plasmas).	June
	• Review of first experimental data	August
	• Experiments in RAID	October
	• Analysis to reach conclusion on feasibility of fs-TALIF measurements in tokamaks.	December

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Thanks for your attention