



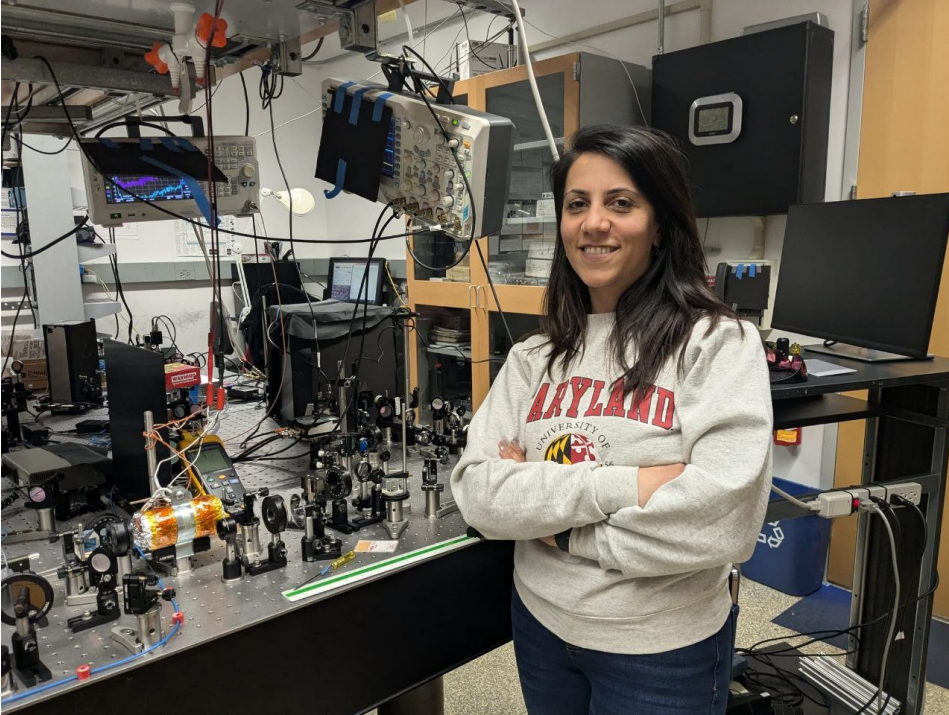
B-PHOT  
BRUSSELS  
PHOTONICS



# Squeezed light sources at different wavelengths for the Einstein Telescope

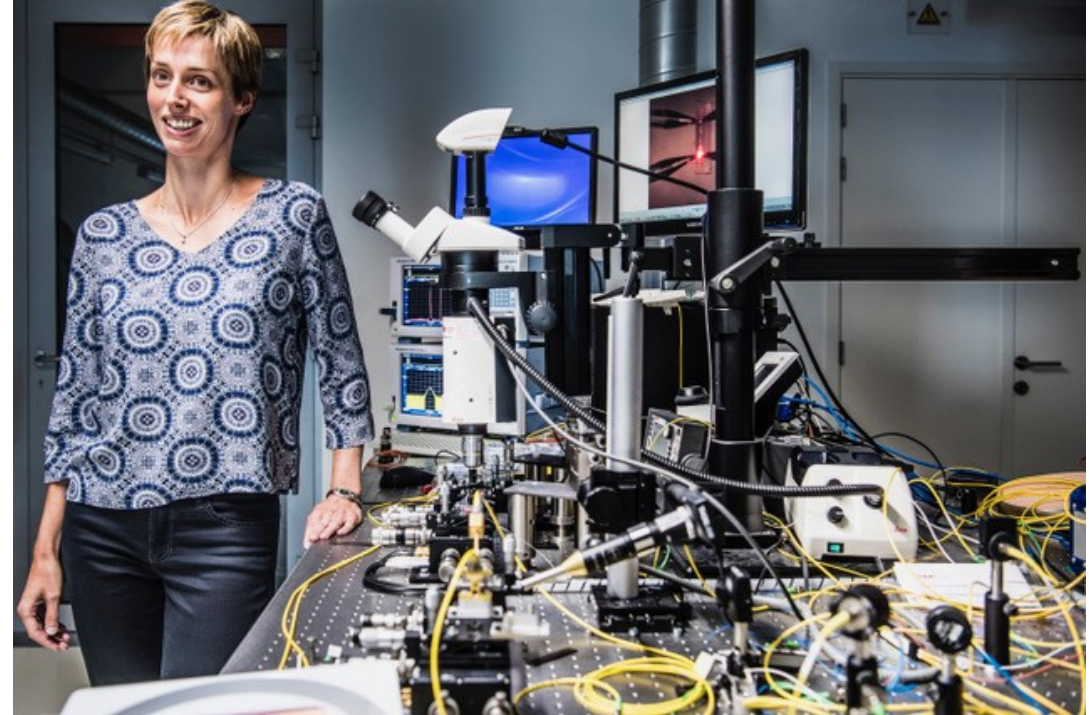
Tatevik Chalyan & Nathalie Vermeulen

## VUB team working on squeezing



**Tatevik Chalyan, postdoctoral researcher at VUB B-PHOT;  
Visiting Researcher at the Joint Quantum Institute,  
University of Maryland 2023-2025**

- **Quantum Squeezing in Rb atomic vapor**
- **Two-Photon Absorption with Squeezed vs Thermal and Coherent States using Ti:Sapphire CW laser**



**Nathalie Vermeulen, professor at VUB B-PHOT**

- **Nonlinear Photonics**
- **Photonics Integrated Circuits**
- **Laser Physics**
- **Teaching Quantum Optics**

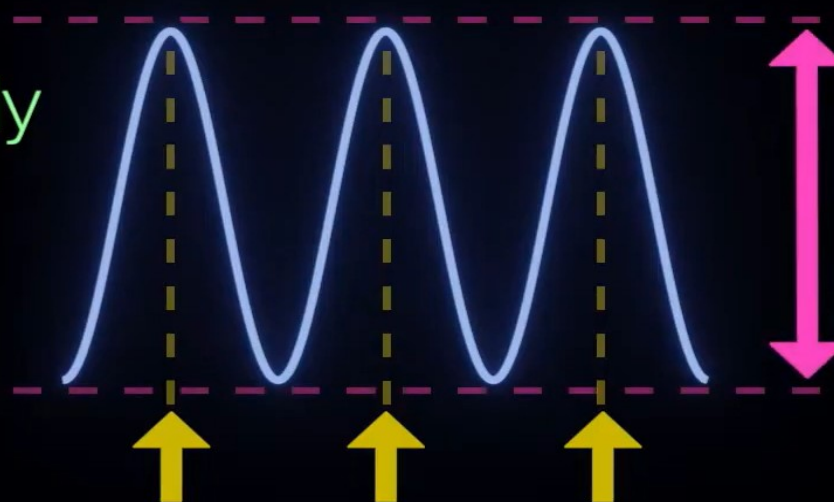


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## Classical Physics

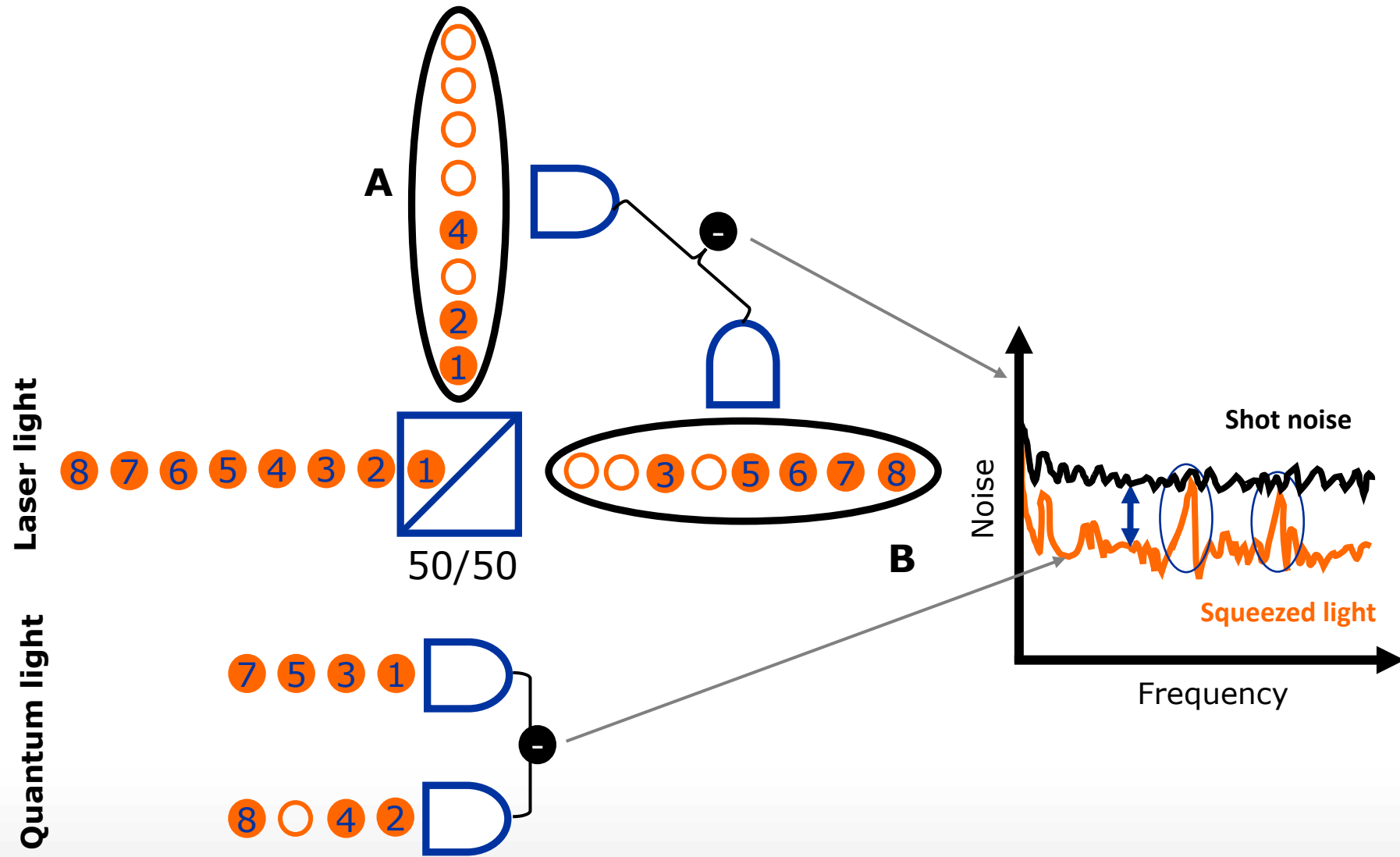
Ideally, researchers would like to precisely control the phase and amplitude of LIGO's lasers



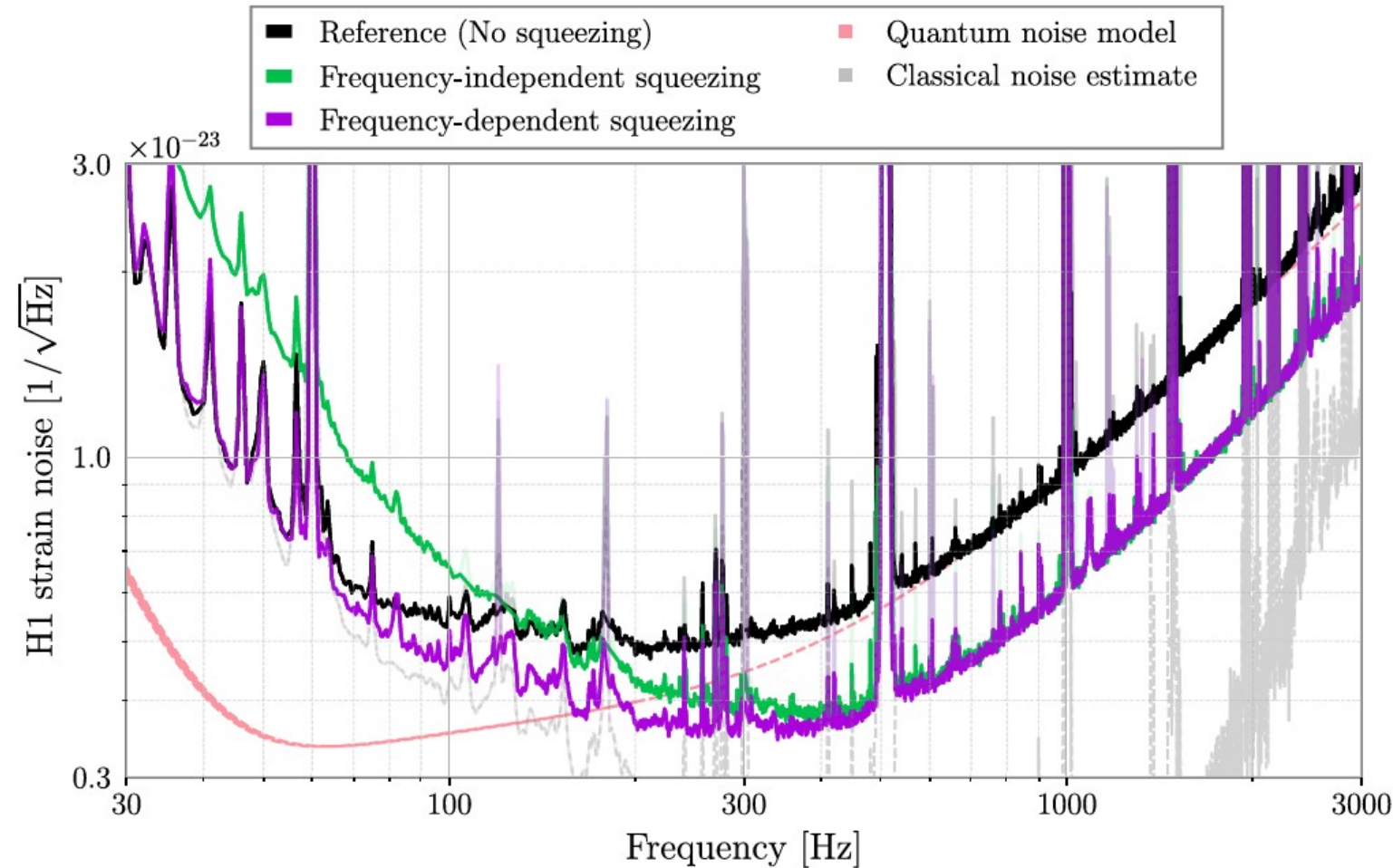
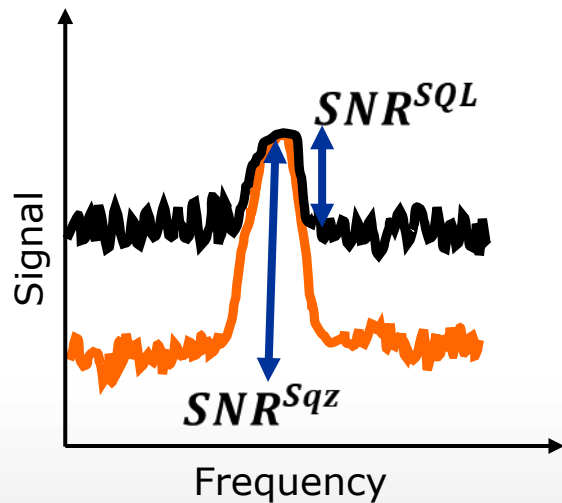
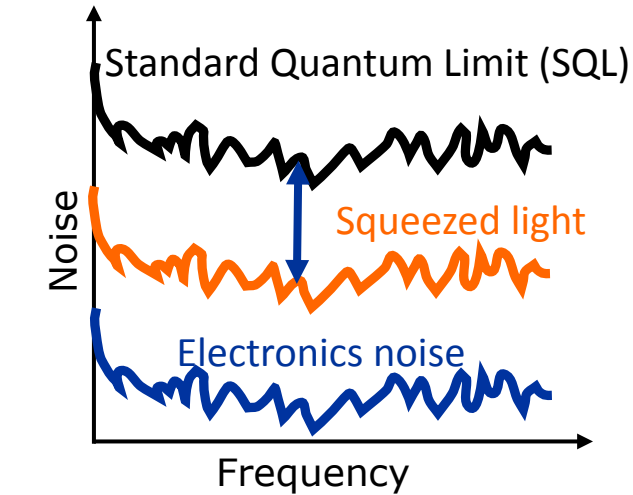
Precise Amplitude

Precise

# Quantum squeezing and its benefits for GWD

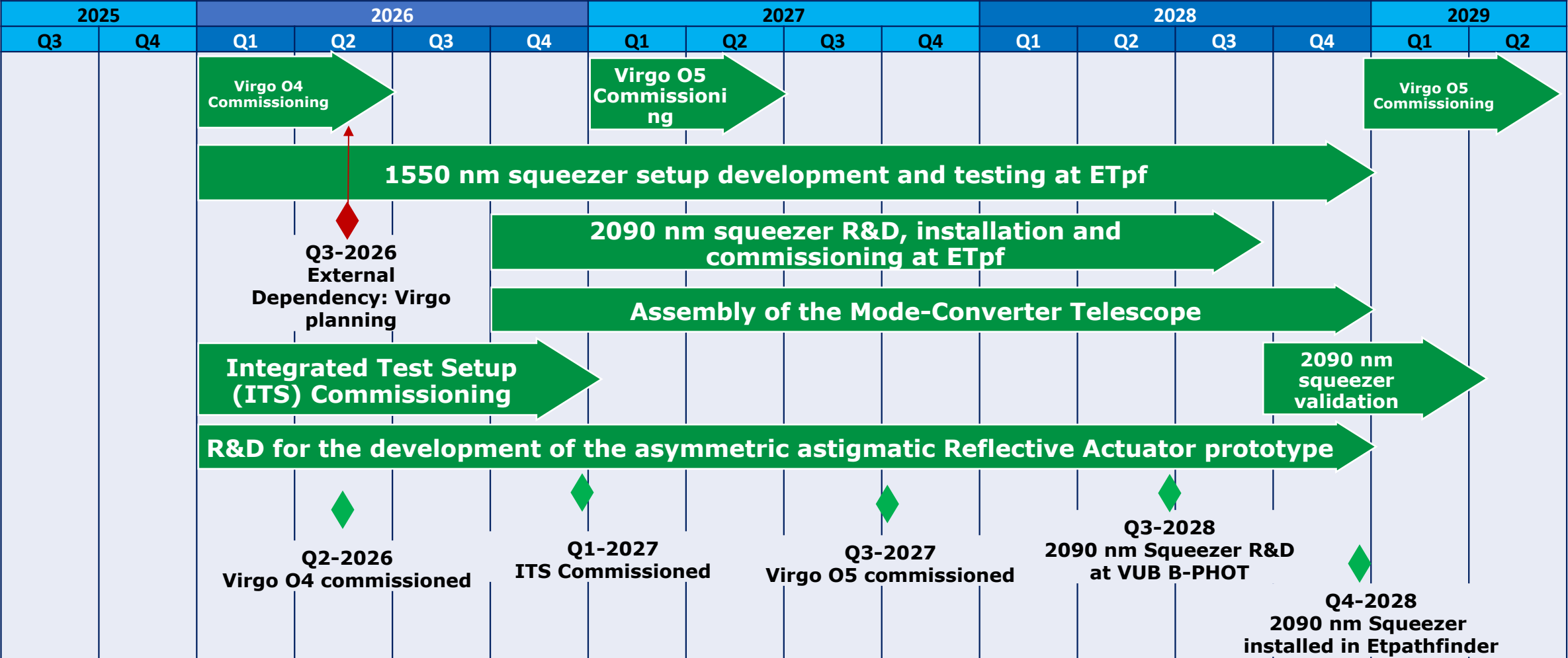


# What is squeezing and why it is important



Broadband Quantum Enhancement of the LIGO Detectors with Frequency-Dependent Squeezing

# WP 2.2 Frequency Dependent Squeezing (VUB/B-PHOT)



- KPI1 - Q3/2026: Virgo O4 commissioning with the improvement of the Mode Converter Telescope's performance at EGO
- KPI2 - Q3/2027: Virgo O5 commissioning with the improved mode matching between the ITF and the squeezer at 1064 nm
- KPI3 - Q1/2027: Achieved stable lock of the reference Fabry-Pérot cavity
- KPI4 - Q1/2029: Develop a fully characterized system for mode-matching sensing, as well as a reflective actuator for ET at 1550 nm
- KPI5 - Q1/2029: Squeezer at 1550 nm down to 10 dB in collaboration with UMaastricht at ET pathfinder
- KPI6 - Q4/2028: Squeezer at 2090 nm down to 8 dB at VUB B-PHOT
- KPI7 - Q1/2029: Squeezer at 2090 nm installed and validated at UMaastricht at ET pathfinder



## Virgo O4 & O5 commissioning

**B-PHOT has been a member of Virgo since September 2024**

T. Chalyan followed/s

- ✓ Virgo detector training
- ✓ Virgo Squeezing subsystem meetings
- ✓ Virgo weekly commissioning meetings

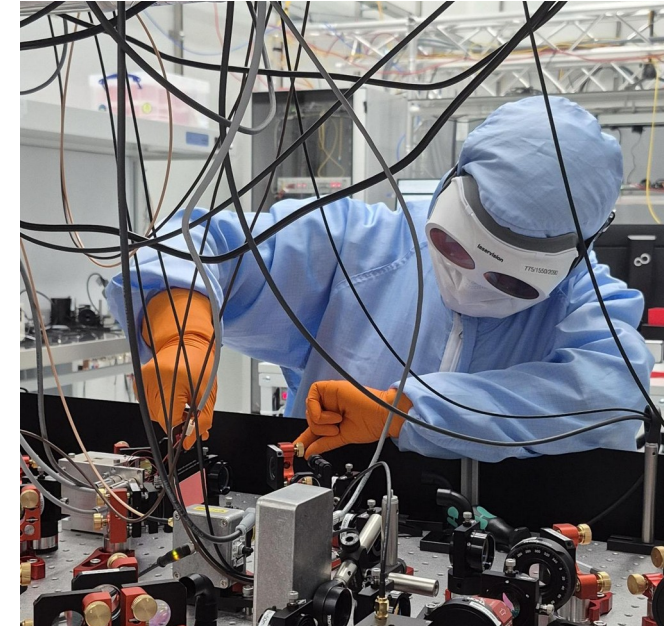
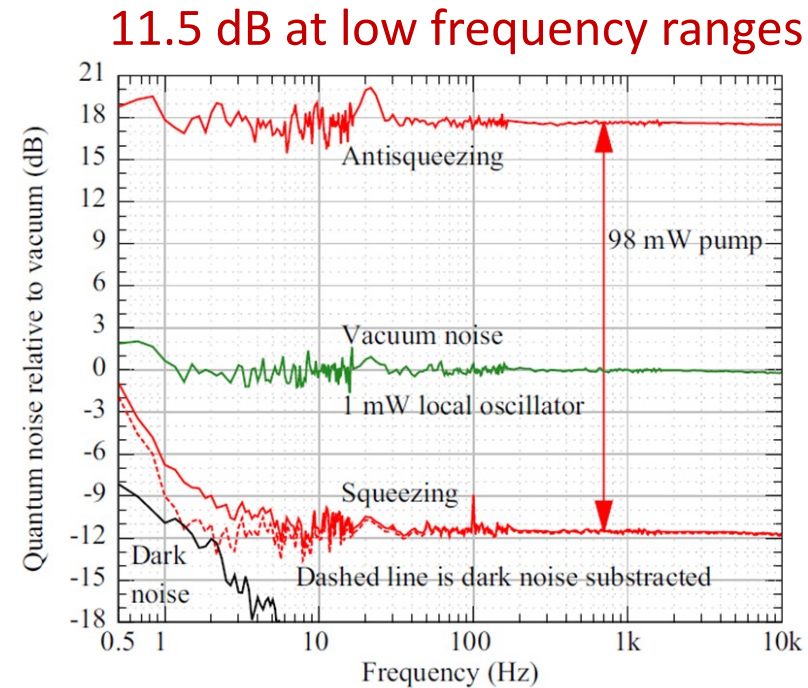
T. Chalyan is getting trained to participate in the commissioning of the squeezer actively. Timing is to be defined by Virgo.

**B-PHOT's contribution to Virgo O5 Frequency Dependent Squeezing (FDS) activities with 0.4 SVAC:**

- Subcarrier laser source upgrades, such as the addition of a modulator and other components to optimize the laser source control.
- SQB1 (suspended) and EQB1 (non-suspended) bench upgrades, characterization, and maintenance.



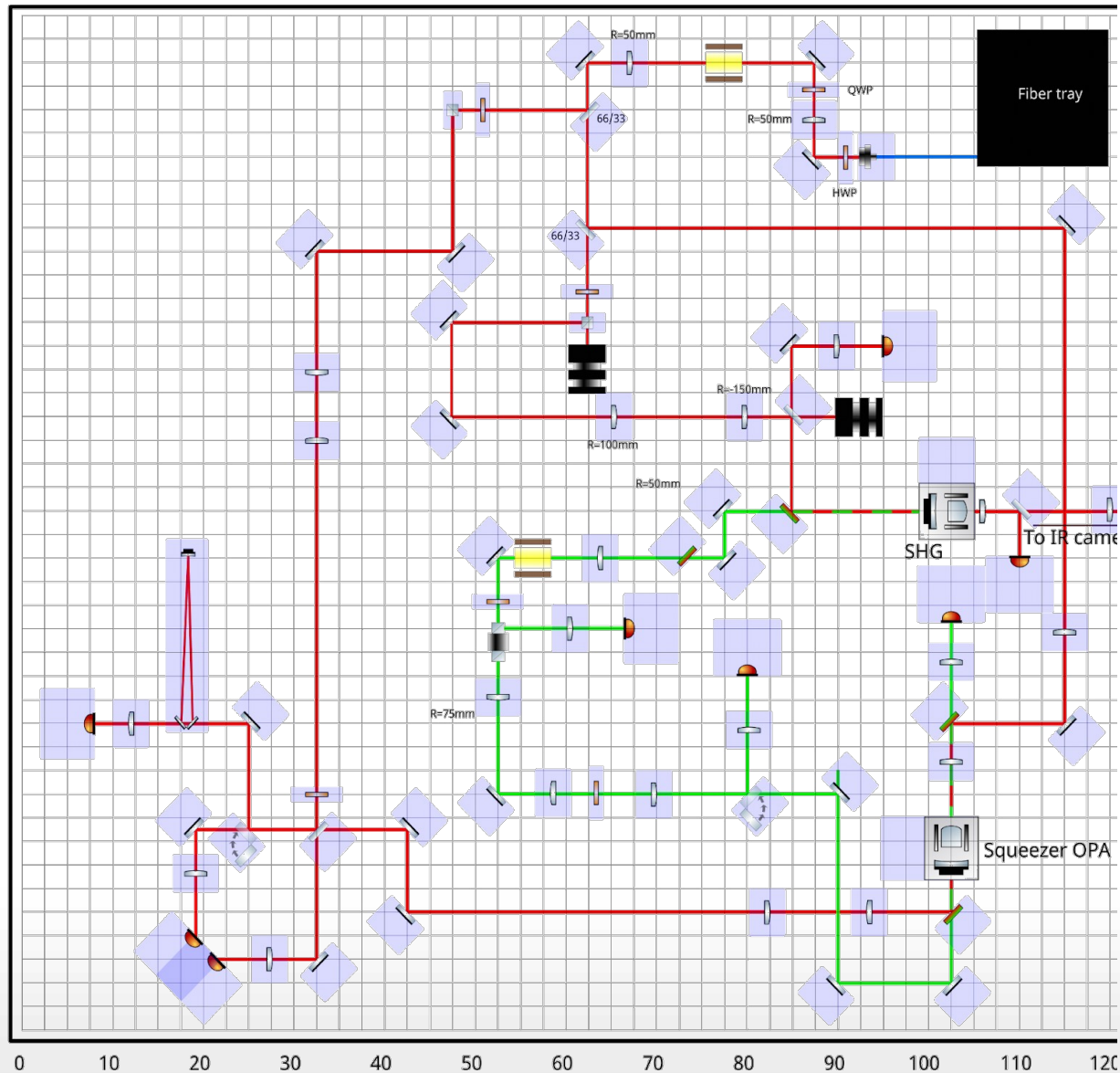
# ETpathfinder Squeezer at 1550 nm @UMaastricht



**B-PHOT collaborates with the UMaastricht team, working on the squeezer for ETpathfinder since May 2024**

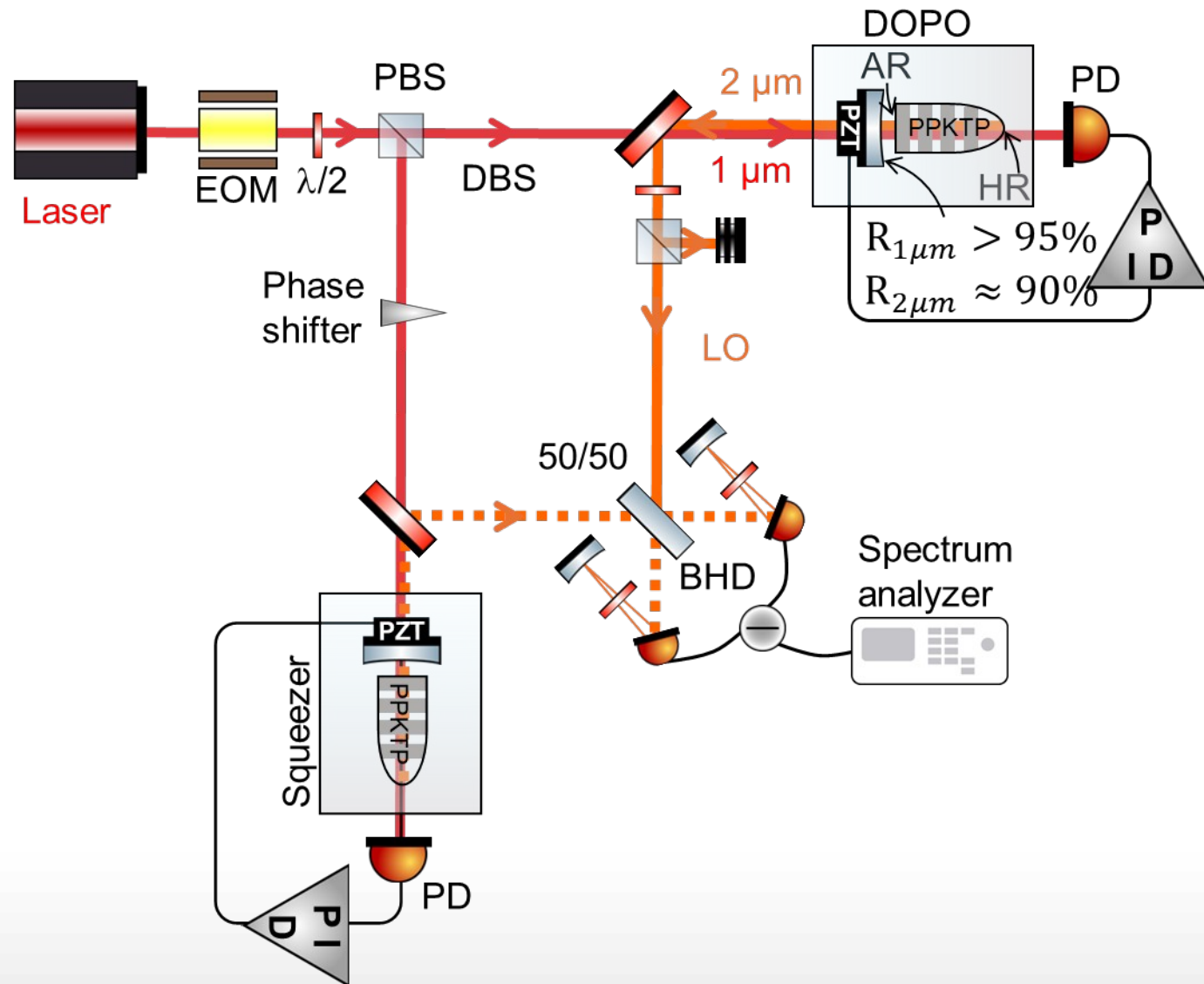


# ETpathfinder Squeezer at 1550 nm @UMaastricht



- The current setup of the squeezer at 1550 nm is missing the coherent control;
- So far only 5.5 dB squeezing has been achieved (the goal is at least 10 dB);
- Sources of losses need to be identified and eliminated;
- Tests in vacuum need to be performed.

## Next step: squeezing at 2090 nm at VUB B-PHOT together with UMaastricht



**Candidates for the laser:** Ti:Sapphire

tunable laser to reach 1045 nm;

**Nonlinear crystal:** Periodically poled KTP (PPKTP);

**Photodetectors for 2090 nm:** InGaAs high-sensitivity PIN photodiode with extended range detection.

**Coherent control:** like in LIGO, done with 2 AOMs.

The concept is based on C. Darsow-Fromm et al. Opt. Lett. 46, 5850-5853, 2021.

# Light source: Ti:Sapphire CW laser

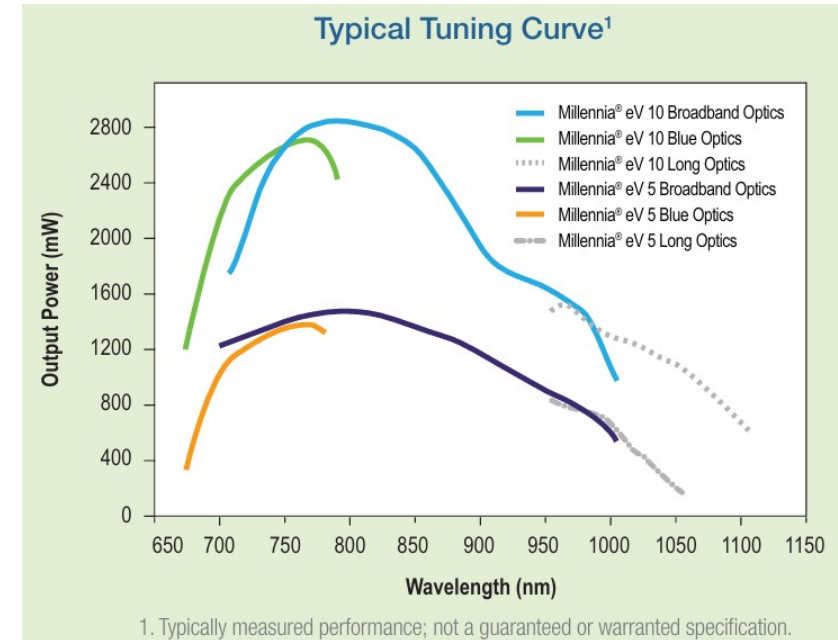


Millennia pump power = 10 W  
Millennia power stability  $\pm 1\%$   
Millennia noise  $< 0.04\%$  rms  
Power at 1045 nm  $\approx 0.5$  W



3900 CW Ti:Sapphire laser (We have @B-PHOT)  
Power at 1045 nm  $\approx 0.5$  W  
Noise  $< 1\%$

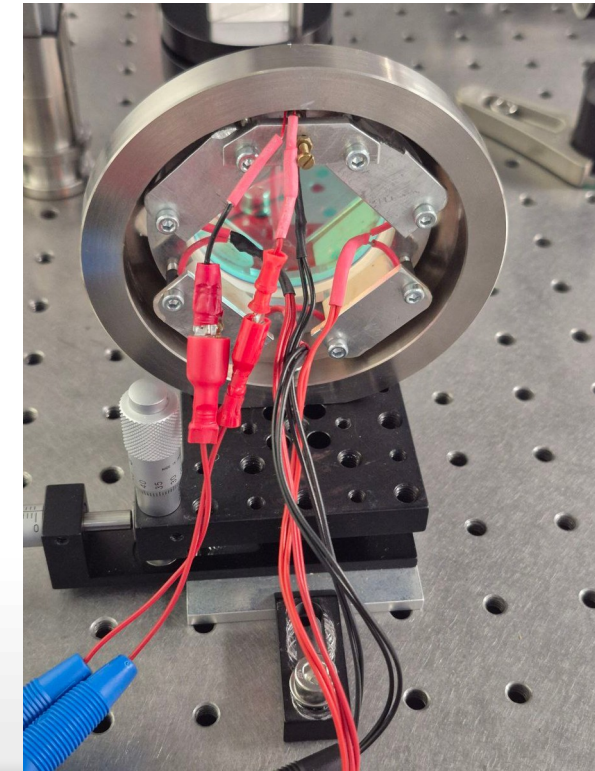
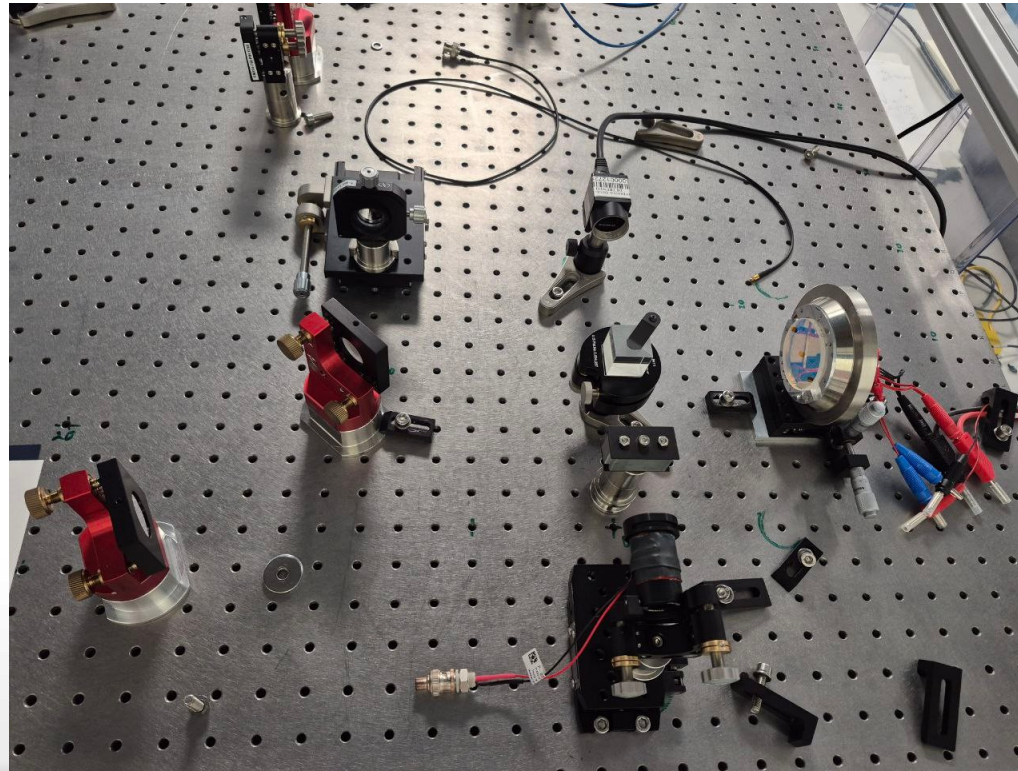
**Alternative for the future Matisse CS with  $< 35$  kHz in 100 $\mu$ s (0.07 fm)**





# Collaboration with University of Trento and Gran Sasso Science Institute

- Assembly of the Mode-Converter Telescope to couple the squeezed field to the interferometer
  - Integrated Test Setup (ITS) Commissioning
  - R&D for the development of the asymmetric astigmatic Reflective Actuator prototype
- 
- ✓ **First visit and training are done in February 2026**
  - ✓ **Participating in setup characterization with a master student at UniTN**



## What next for 2026?

- Further development of the 1550 nm squeezer at UM
- 2090 nm squeezer setup development at VUB Halle campus:
  - Order and assembly of Ti:Sapphire laser
  - Laser characterization, stability validation at 1045 nm
  - Cavity simulations with Finesse
  - Coating requirement establishments based on the exact laser wavelength
- Further collaboration with the group at UniTN

**Thank you!**