FLARE

FACULTY OF SCIENCE, MATHEMATICS AND COMPUTING SCIENCE

Rienk Jongma

First Lasing of the THz FEL

***F**ree-electron*
***L**aser for*
***A**dvanced spectroscopy and high-*
***R**esolution*
***E**xperiments*

Radboud University Nijmegen

IN DEI NOMINE FELICITER

http://www.ru.nl/flare

Contents

- **Motivation for FLARE**
- **FLARE**
  - Design and construction
  - First lasing
  - Status
- **Extension of the FEL facility**

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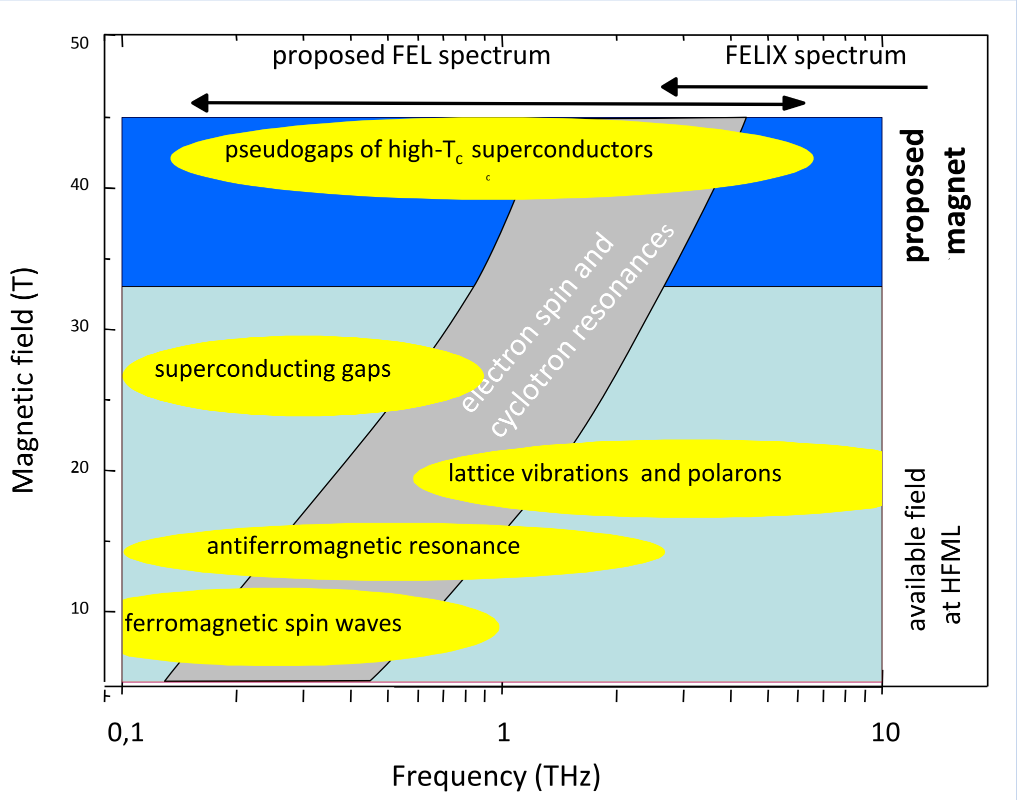
FLARE applications

- **The combination with Very High Magnetic Fields → advanced ESR/EPR thanks to the HFML⁺**



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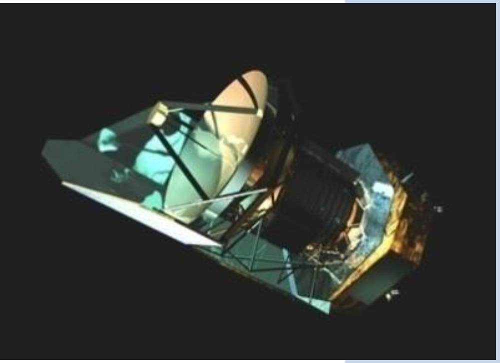
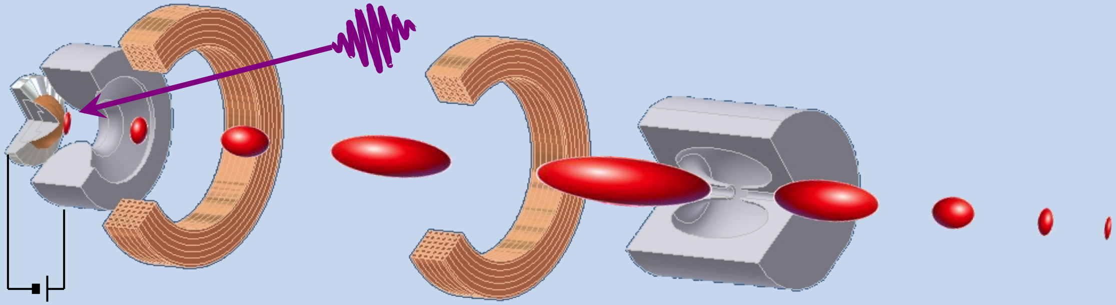
FLARE applications

- **Molecular THz spectroscopy**
  - **Action Spectroscopy** → FELIX-like experiments at longer wavelengths
  - Spectroscopy at very **low T** (helium droplets → Bochum)
  - Spectroscopy in liquids (low resolution)
  - **High resolution spectroscopy** of astronomically relevant species (HIFI / Herschel)
  - **Ultra-fast electron diffraction** (Luiten/TUE)





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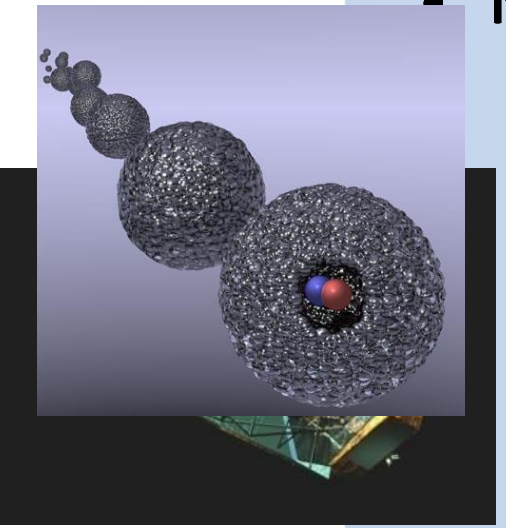
FLARE applications



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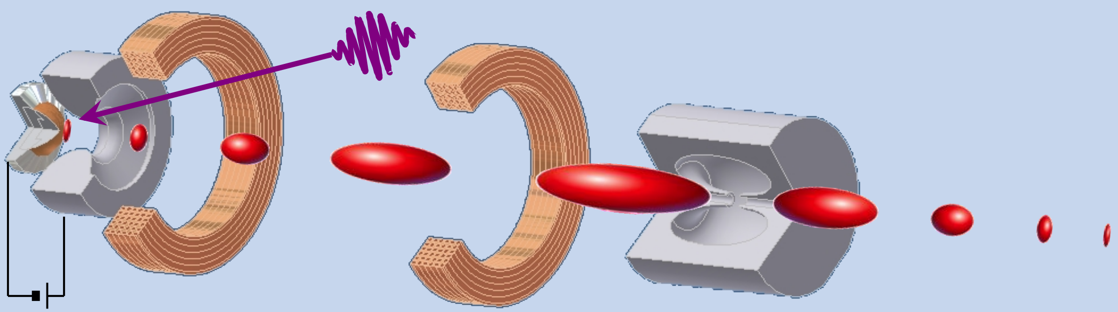
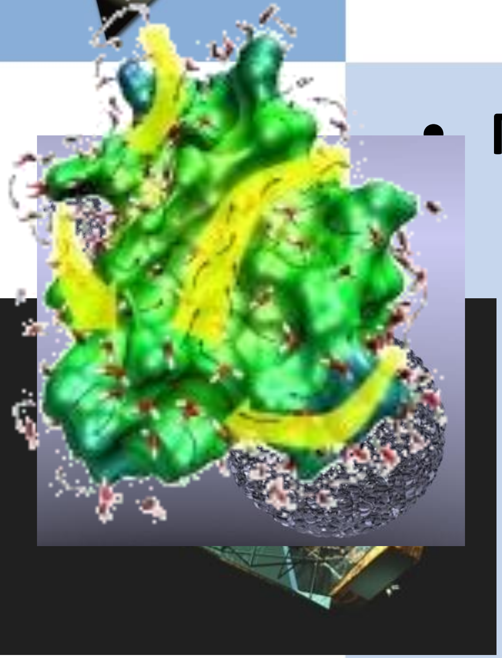


FLARE applications



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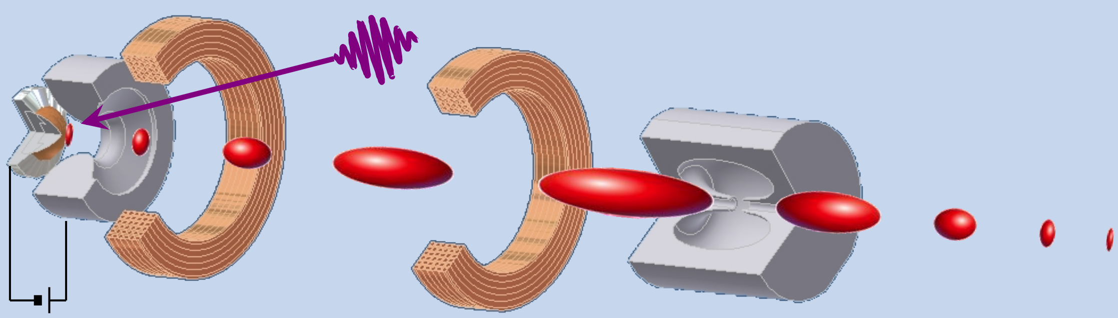

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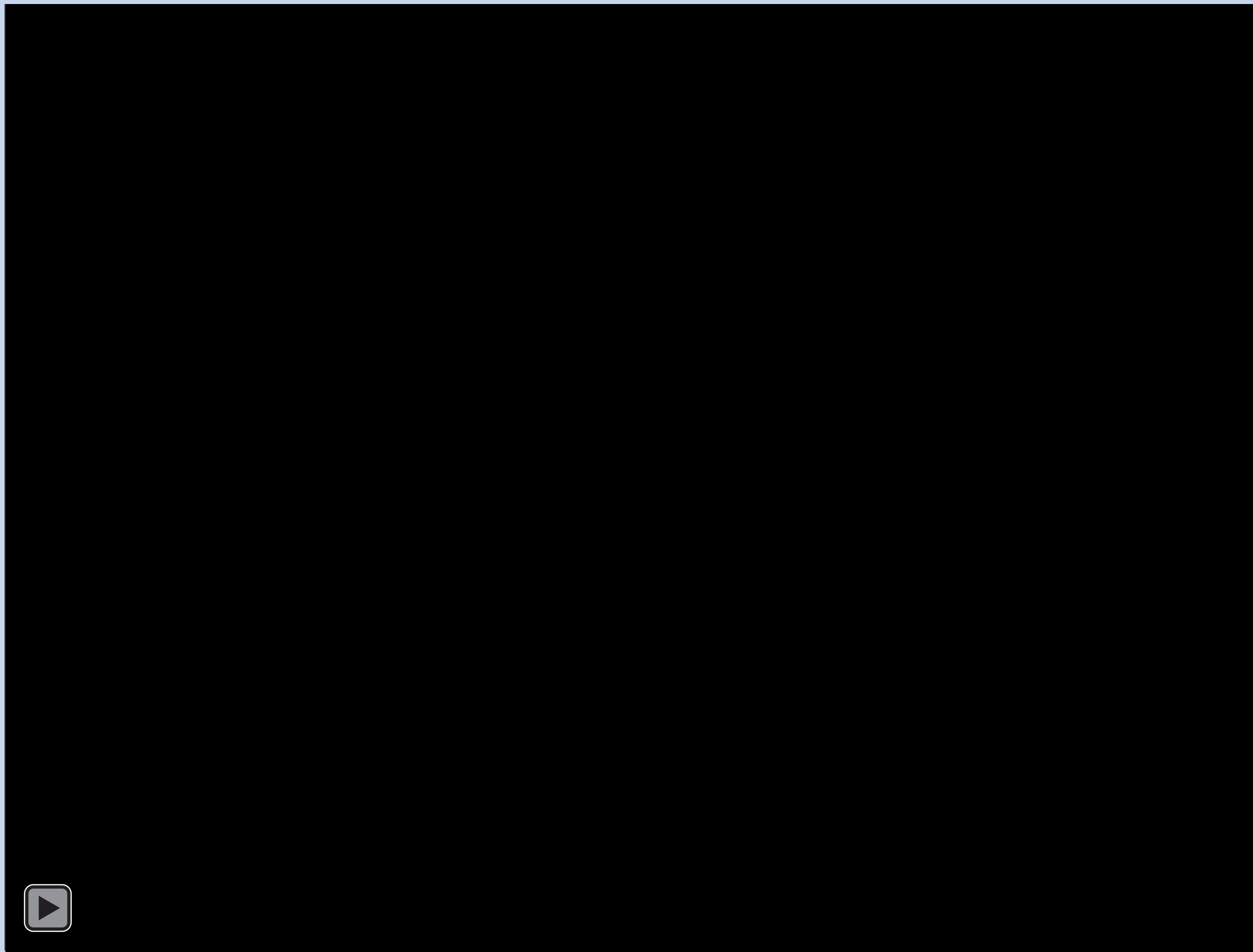
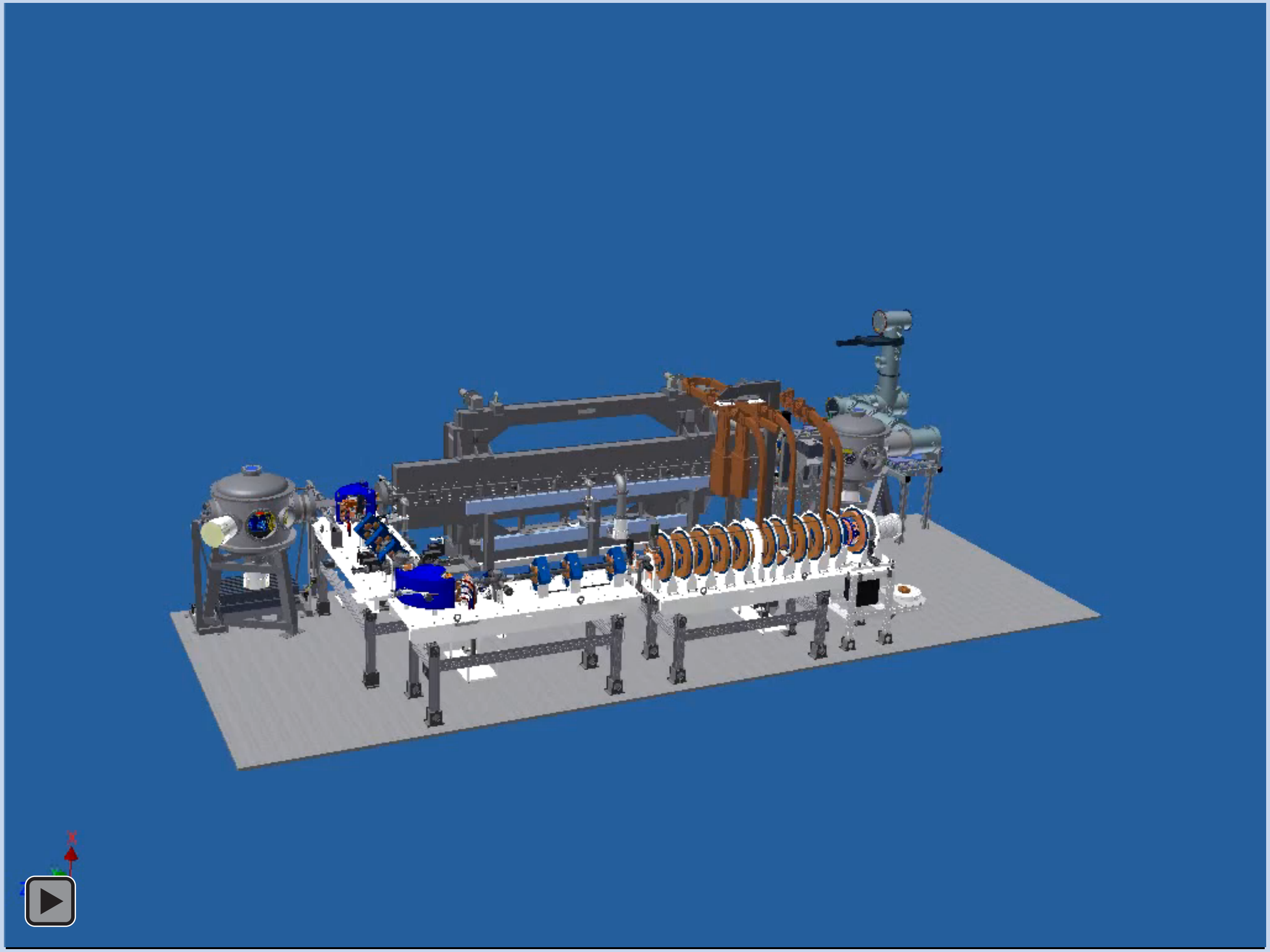
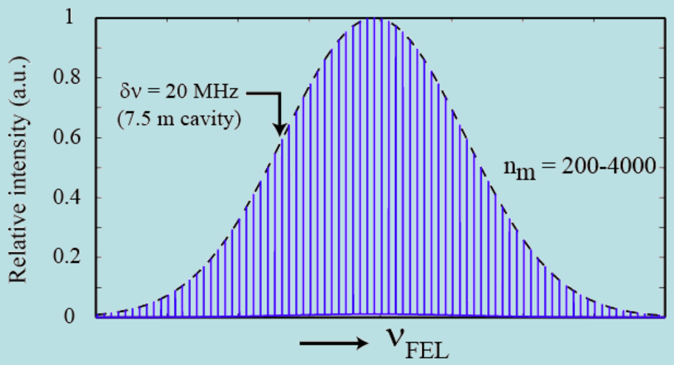
Construction and assembly of FLARE

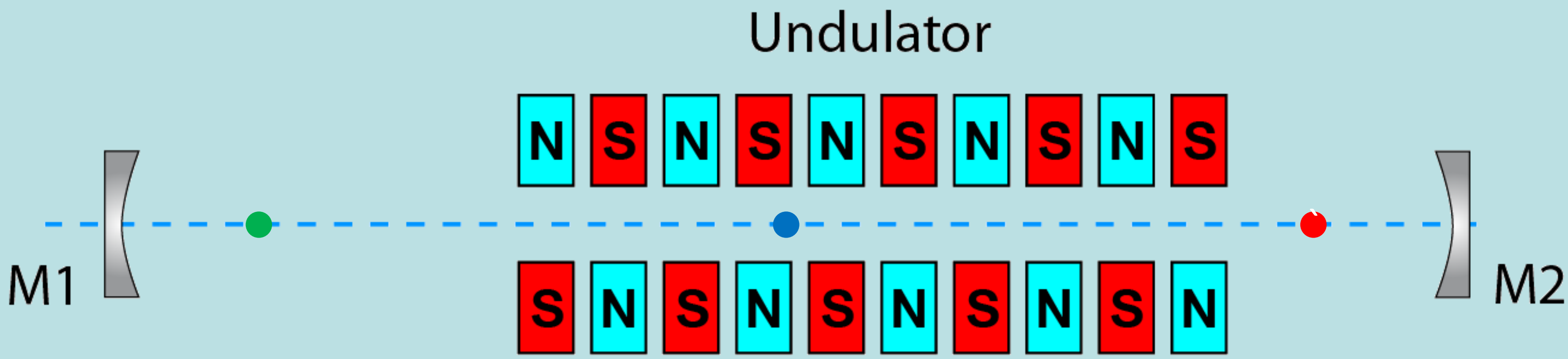


The FLARE system

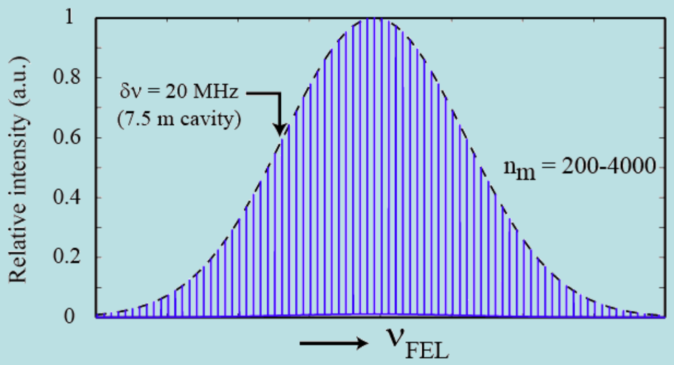


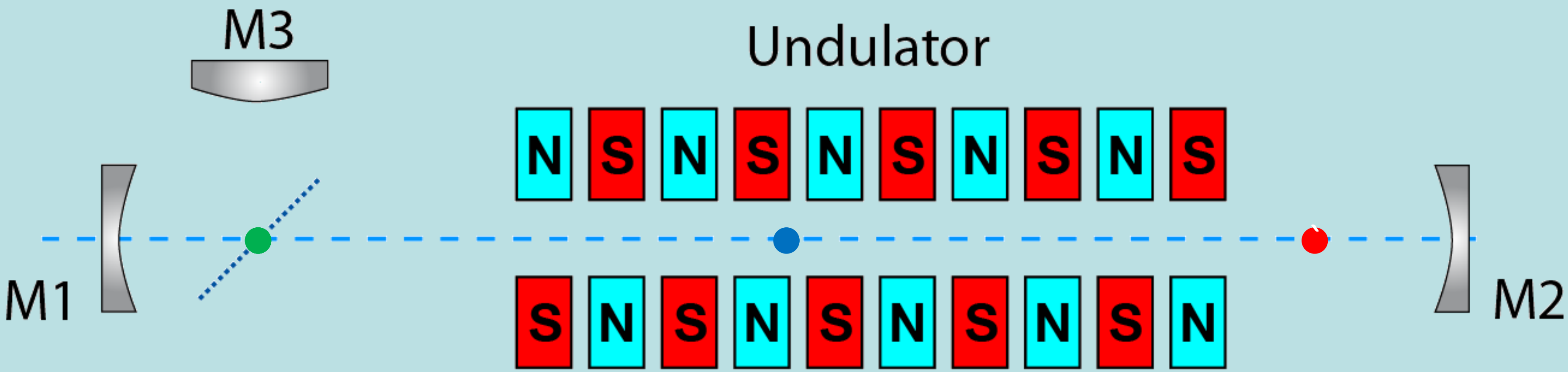
Pump-probe mode



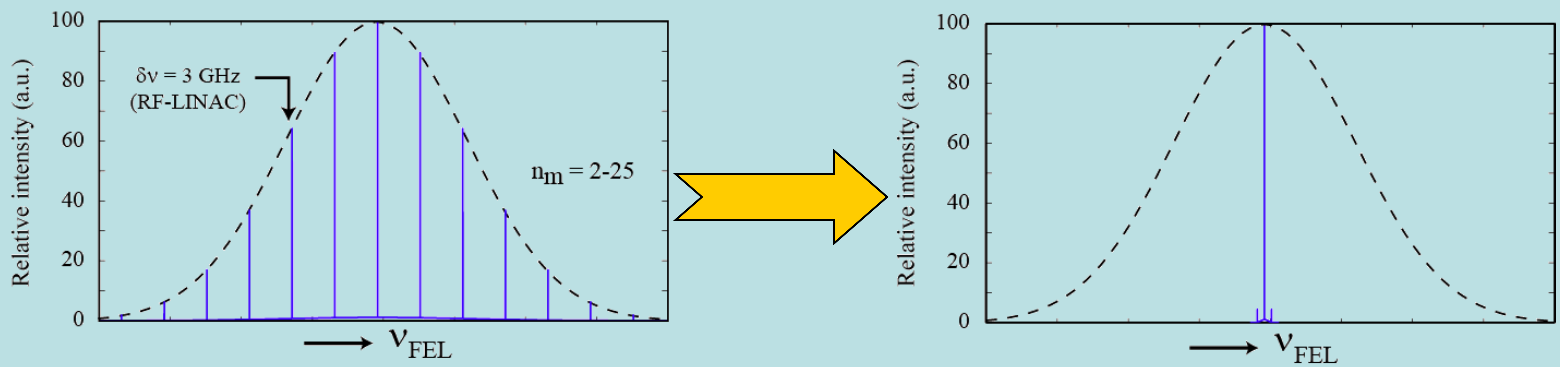


Spectroscopic mode





Spectroscopic mode



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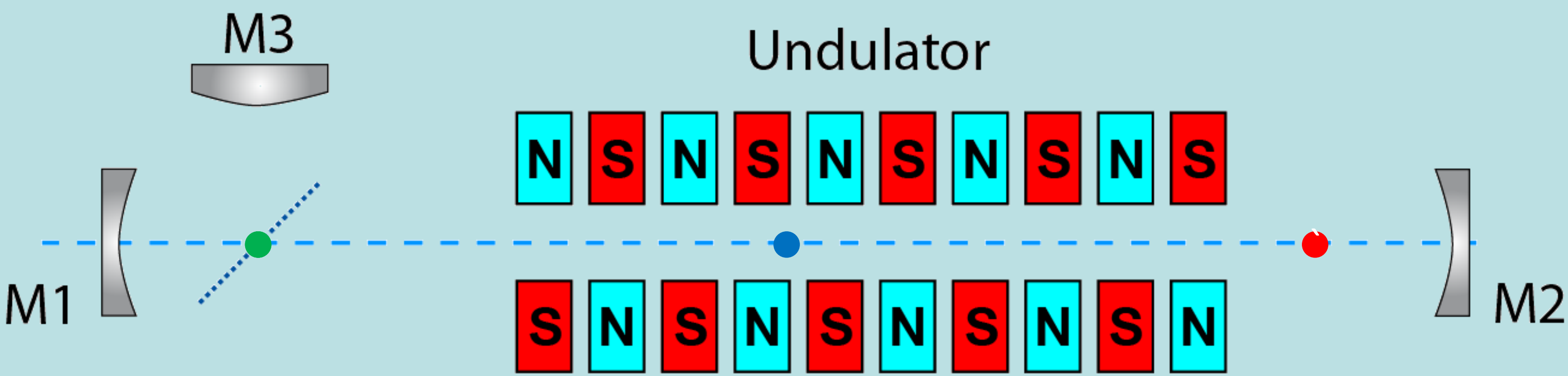
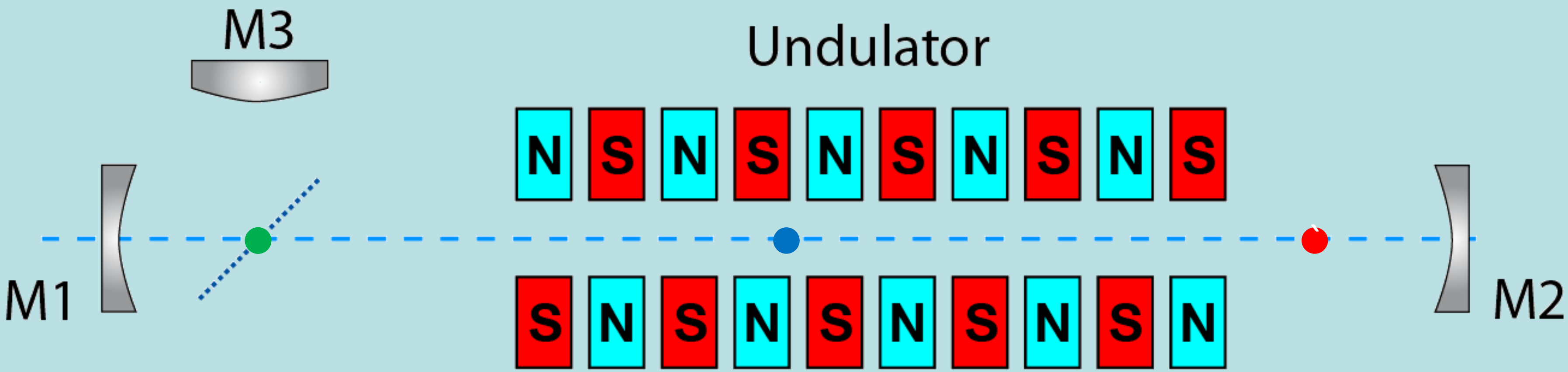
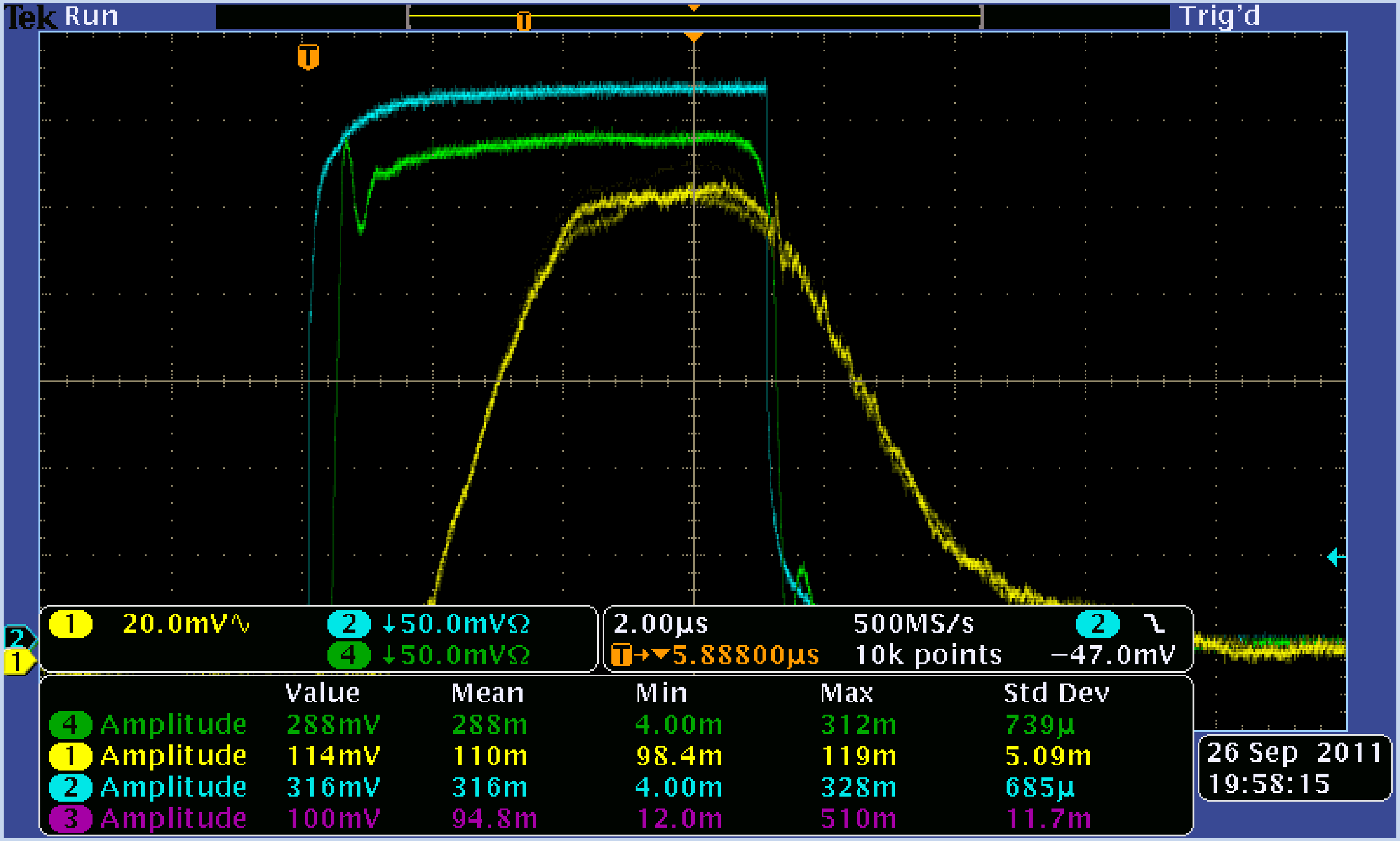


Spectroscopic mode

- **Next step: pulse shaping for EPR/ESR**
  - **First steps towards pulse-shaping: visit poster THPD03 by Szymon Smolarek**



First lasing



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Status of FLARE

- ✅ Lasing and power
- ✅ Spectral range: 100-1400 µm
- ✅ Optical transport to diagnostics station
- ✅ Spectral calibration operational

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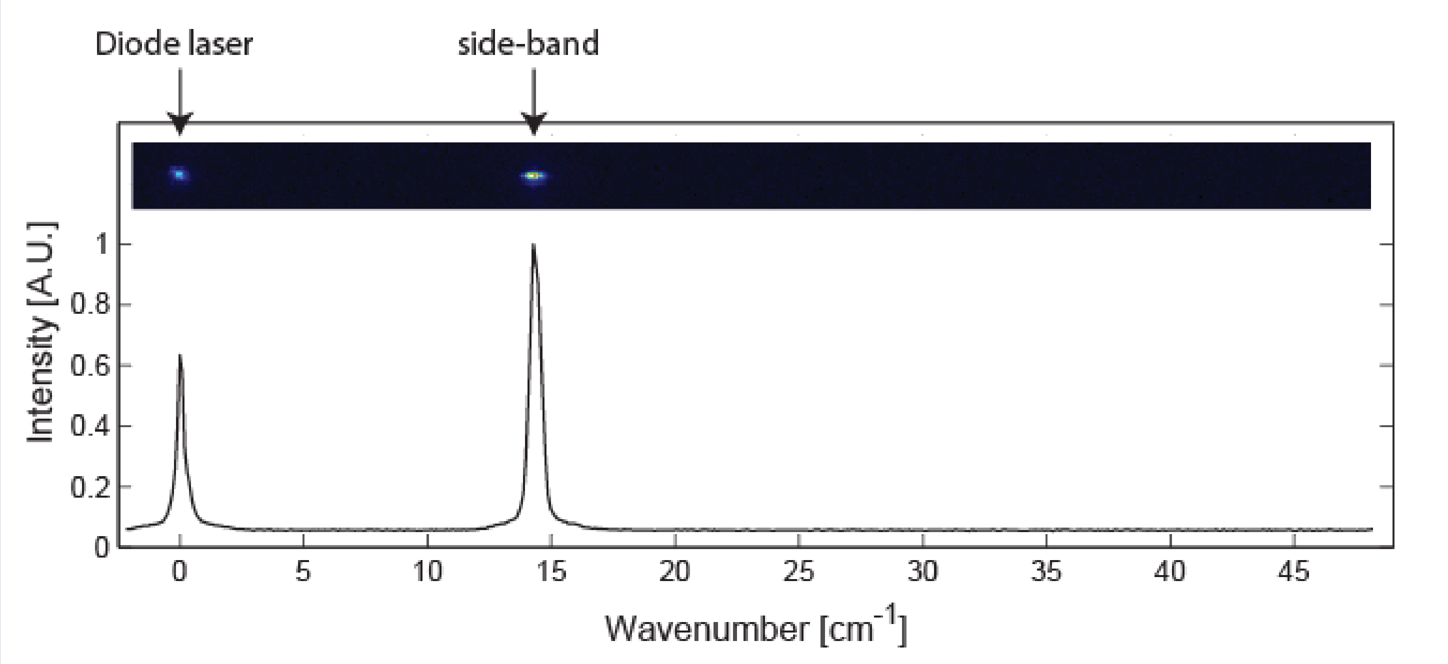
Upconversion results



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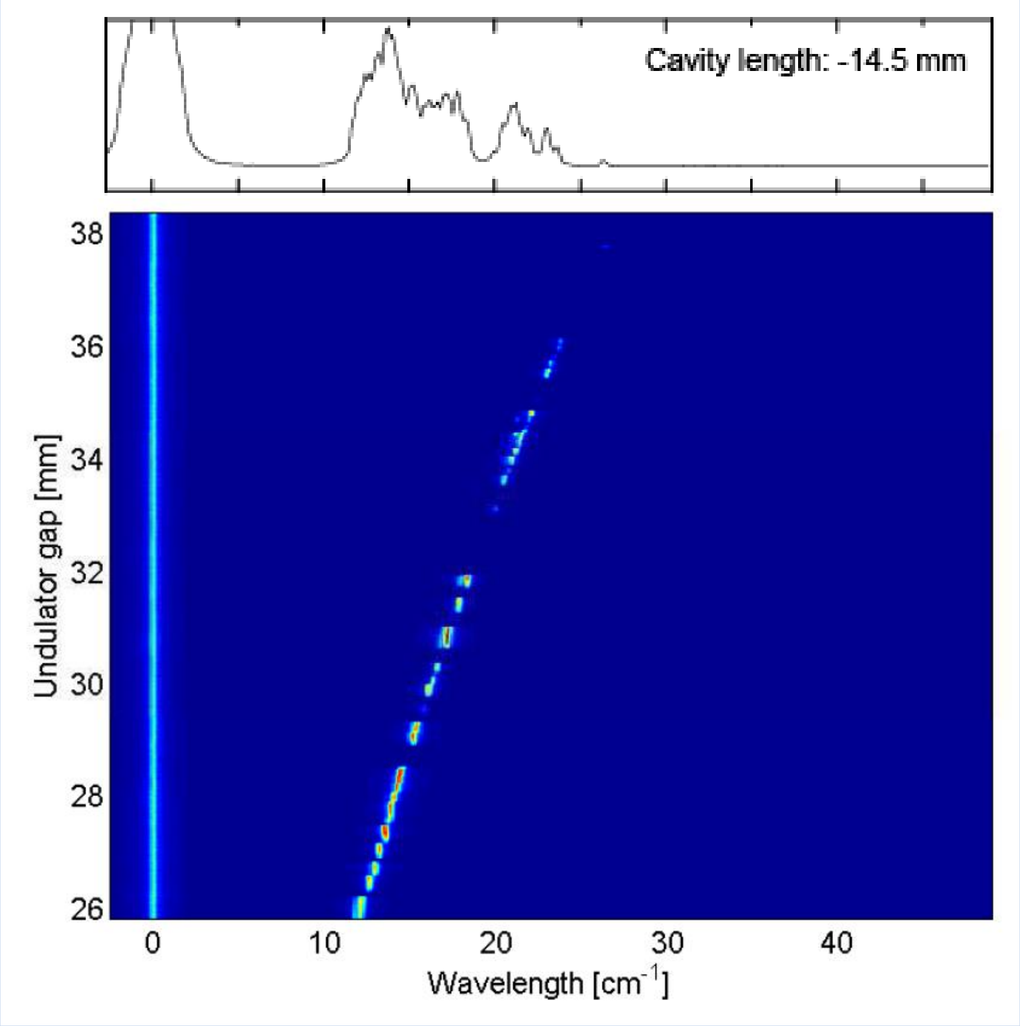
Scanning range



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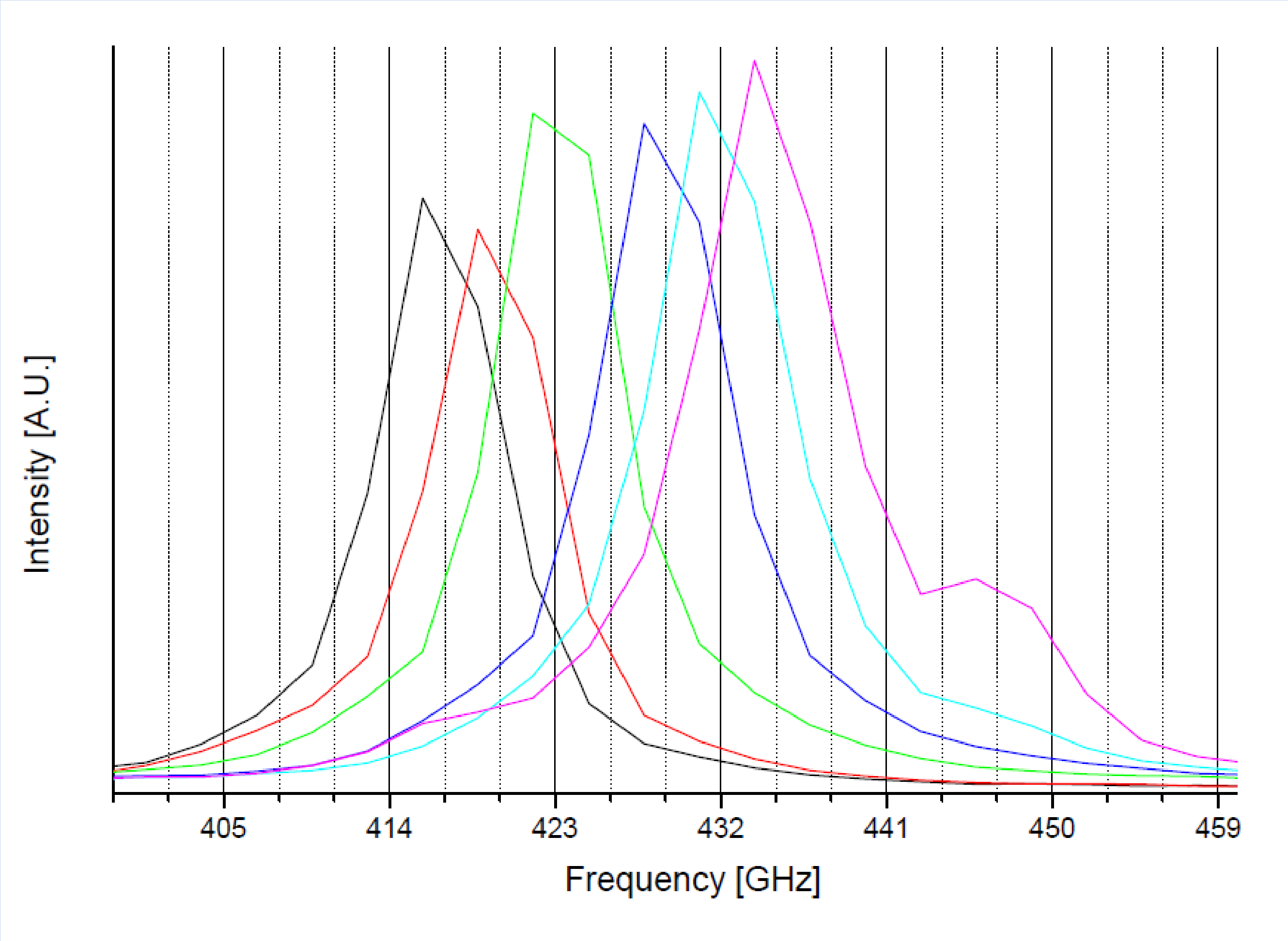
Spontaneous coherence



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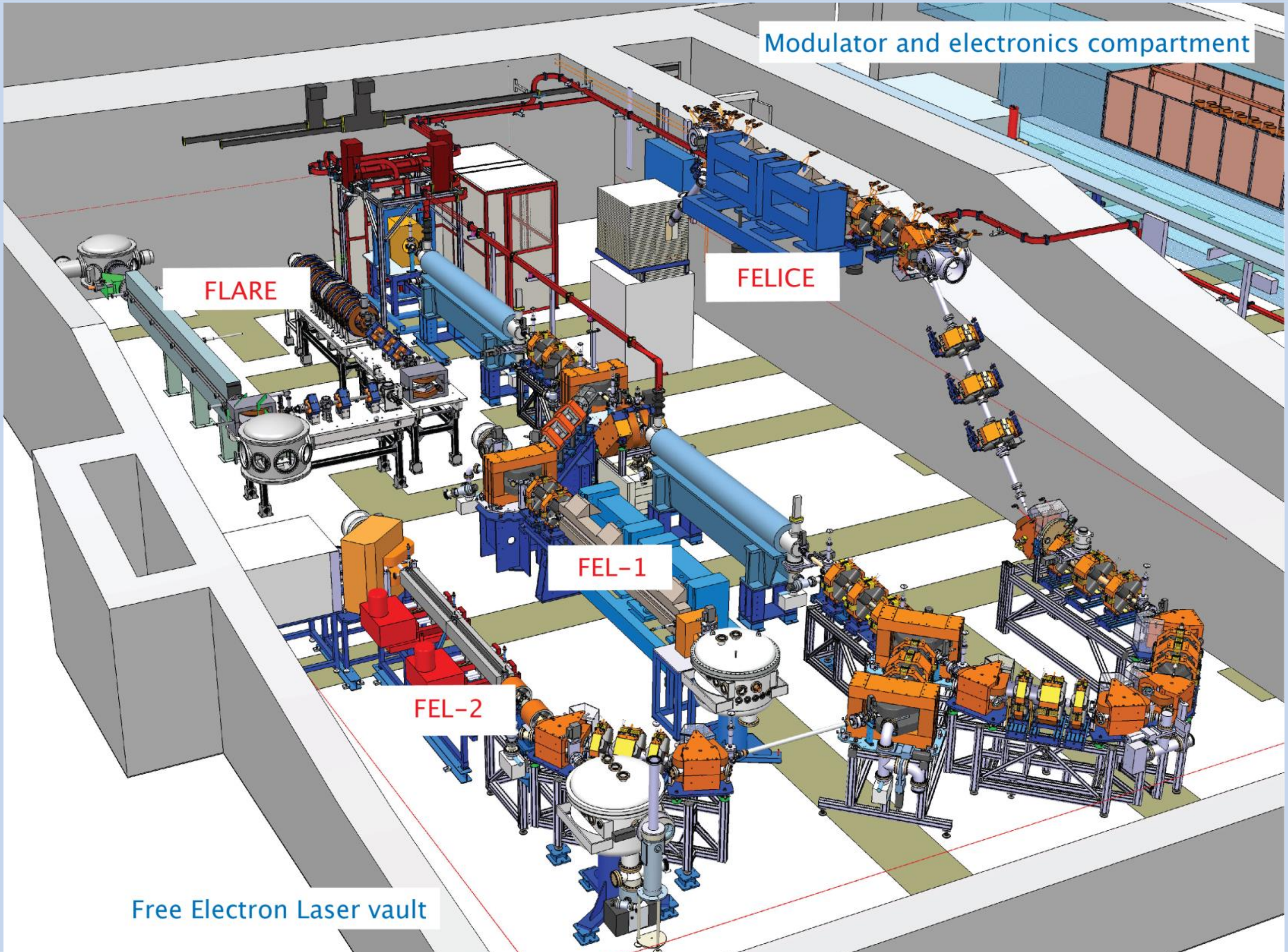
The FELIX facility Nijmegen



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- **Plans for the FELIX facility Nijmegen:**
  - **Wednesday afternoon by Britta Redlich**

Conclusions

- ✔ Lasing and power
- ✔ Spectral range: 100-1400 µm
- ✔ Optical transport to diagnostics station
- ✔ Spectral calibration operational
- ✔ Spontaneous coherence
- ✘ Non-continuous scanning and “difficult” wavelengths
- To be realized:
  - Optical transport to user experiments incl. HFML magnets
  - Completion FELIX / FELICE re-assembly
  - Start of user experiments: 2013

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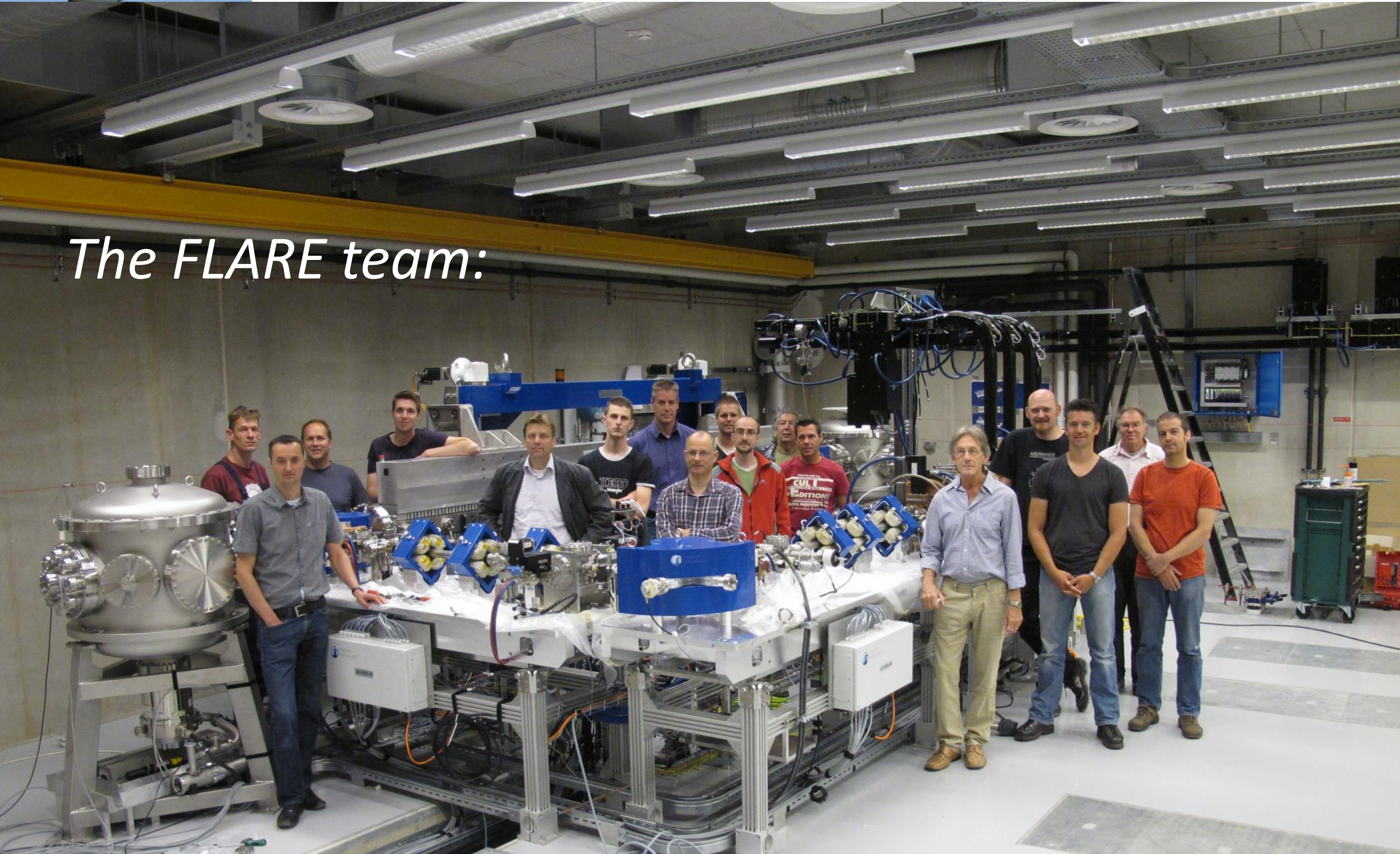
Thanks to:

The FLARE team:



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Thanks to:

- **Support by**
  - **Rijnhuizen and now Radboud University:** Lex van der Meer + FELIX team
  - **Helmholtz-Zentrum Dresden-Rossendorf**: Ulf Lehnert, Rüdi Wünch, Wolfgang Seidel, Peter Michel
  - **Research Instruments GmbH**: Christian Piel + team
- **Financial support**
  - Radboud University
  - FOM and NWO

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The FLARE system

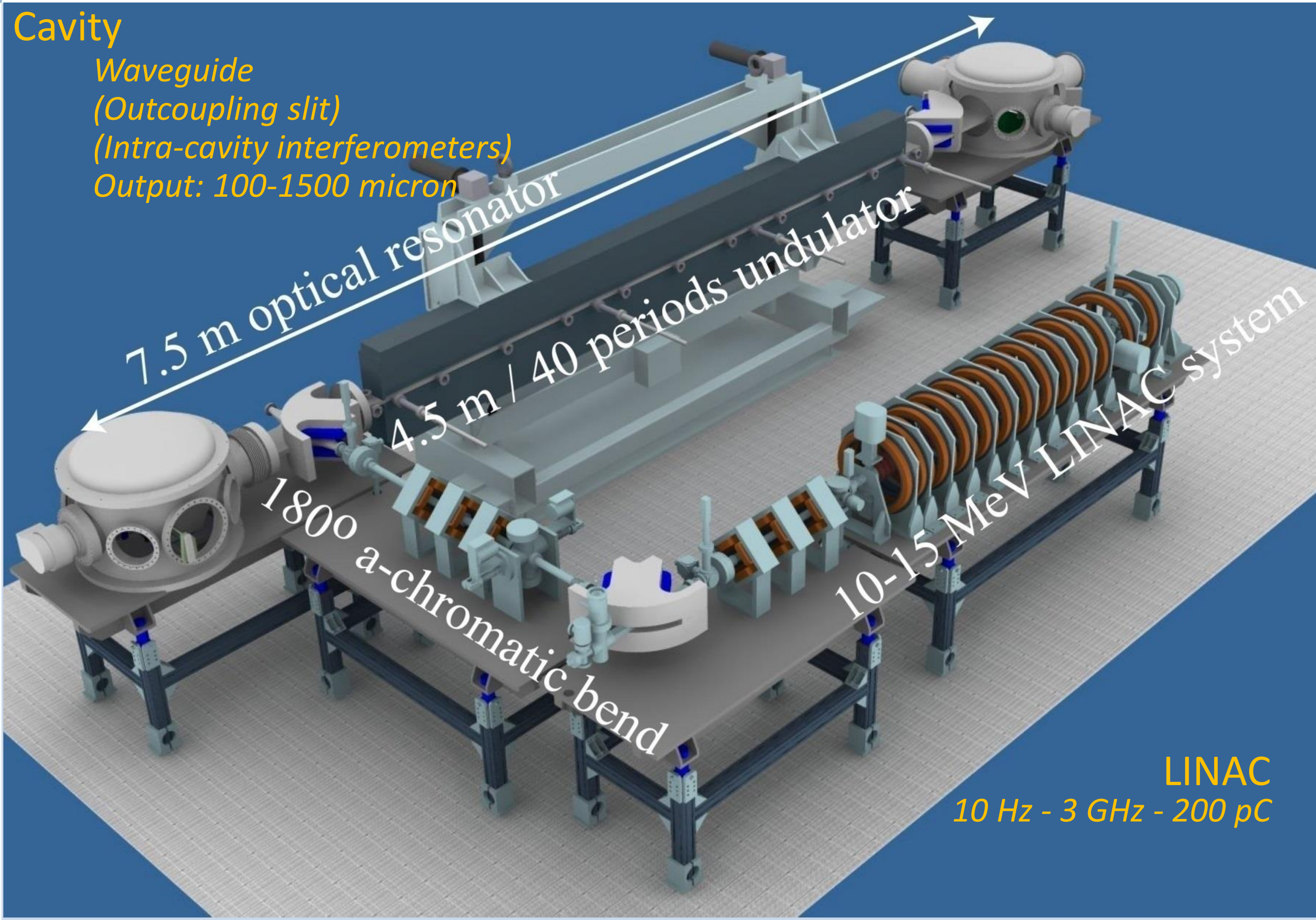
Cavity

Waveguide

(Outcoupling slit)

(Intra-cavity interferometers)

Output: 100-1500 micron



LINAC

10 Hz - 3 GHz - 200 pC

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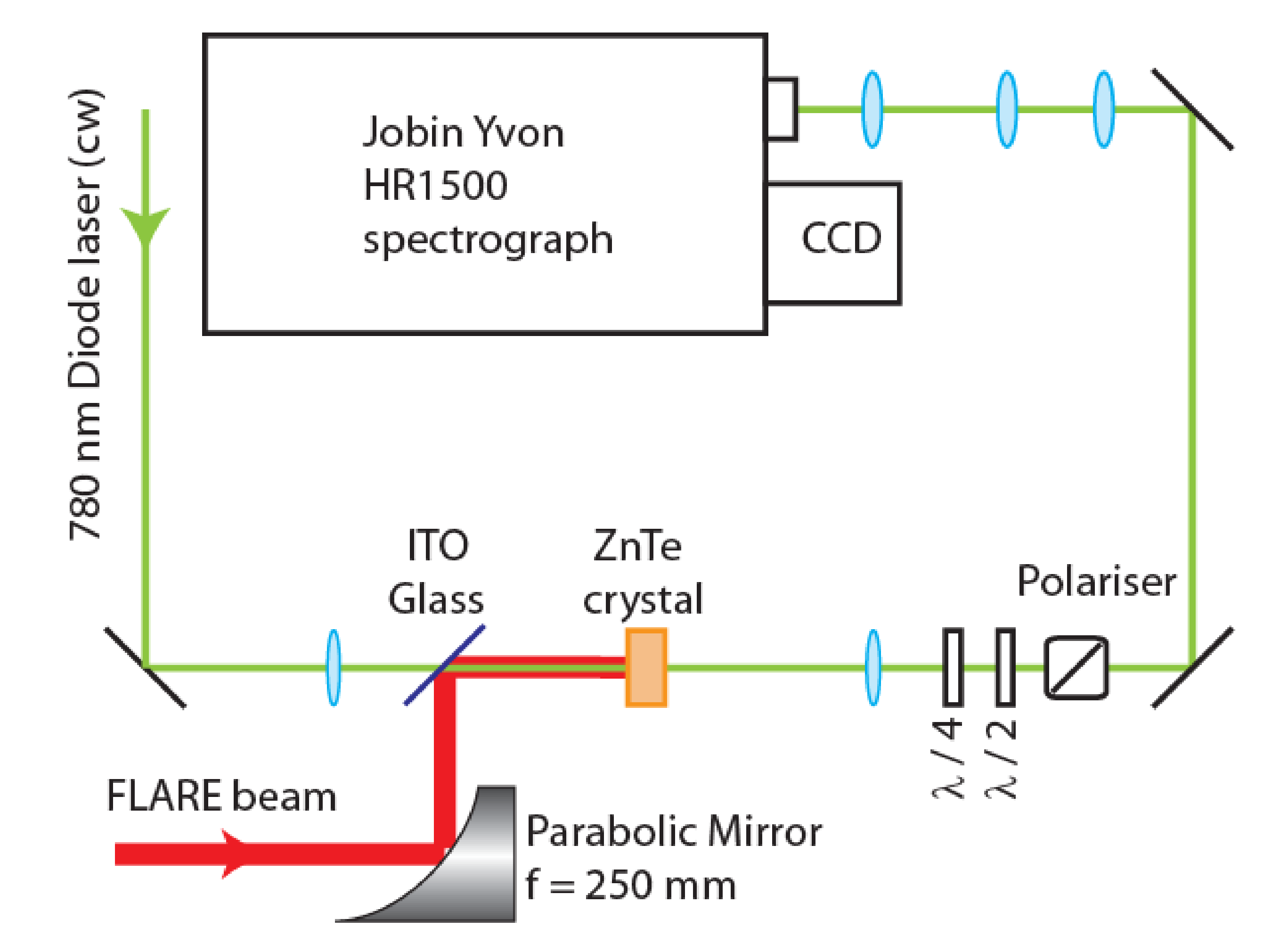
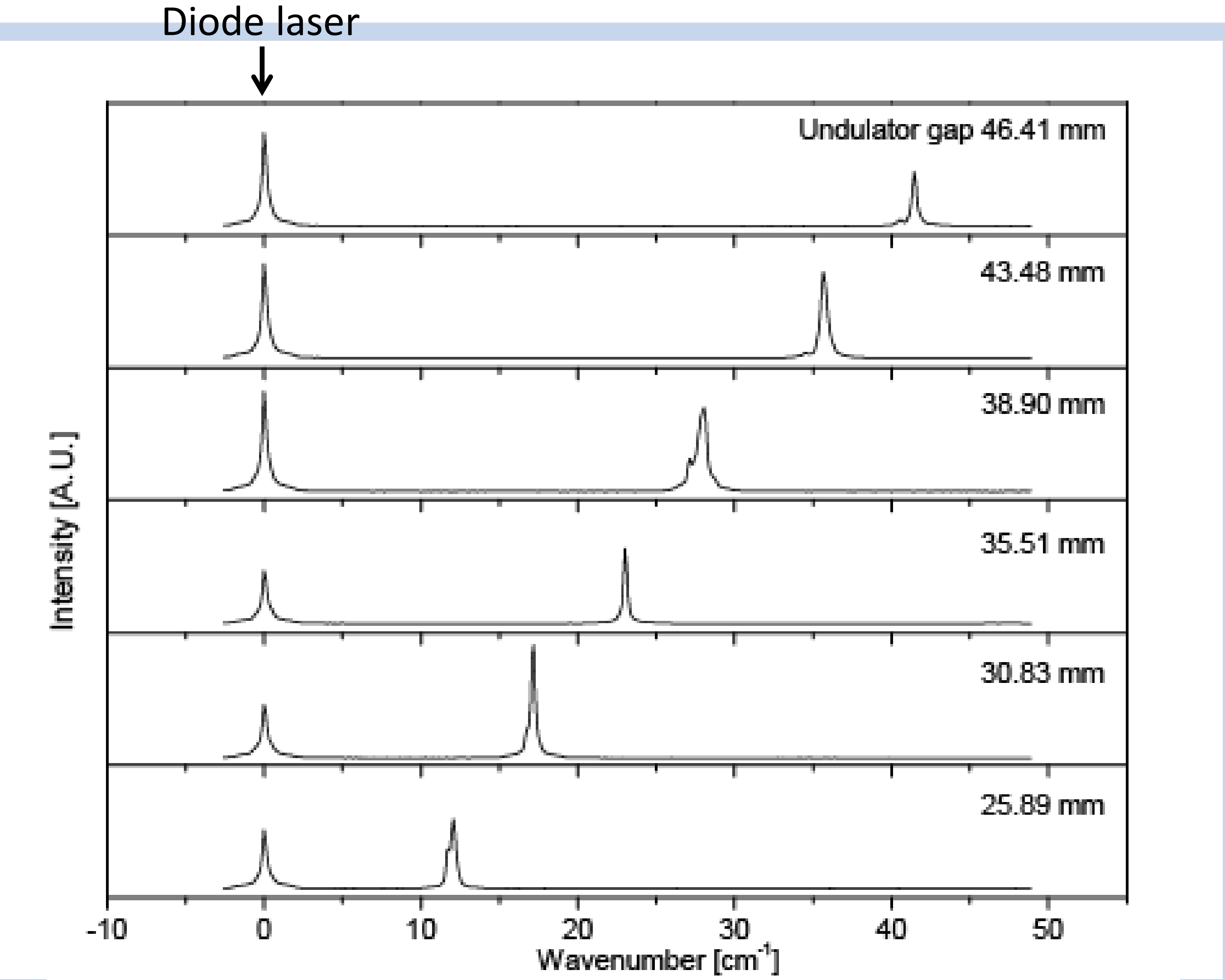
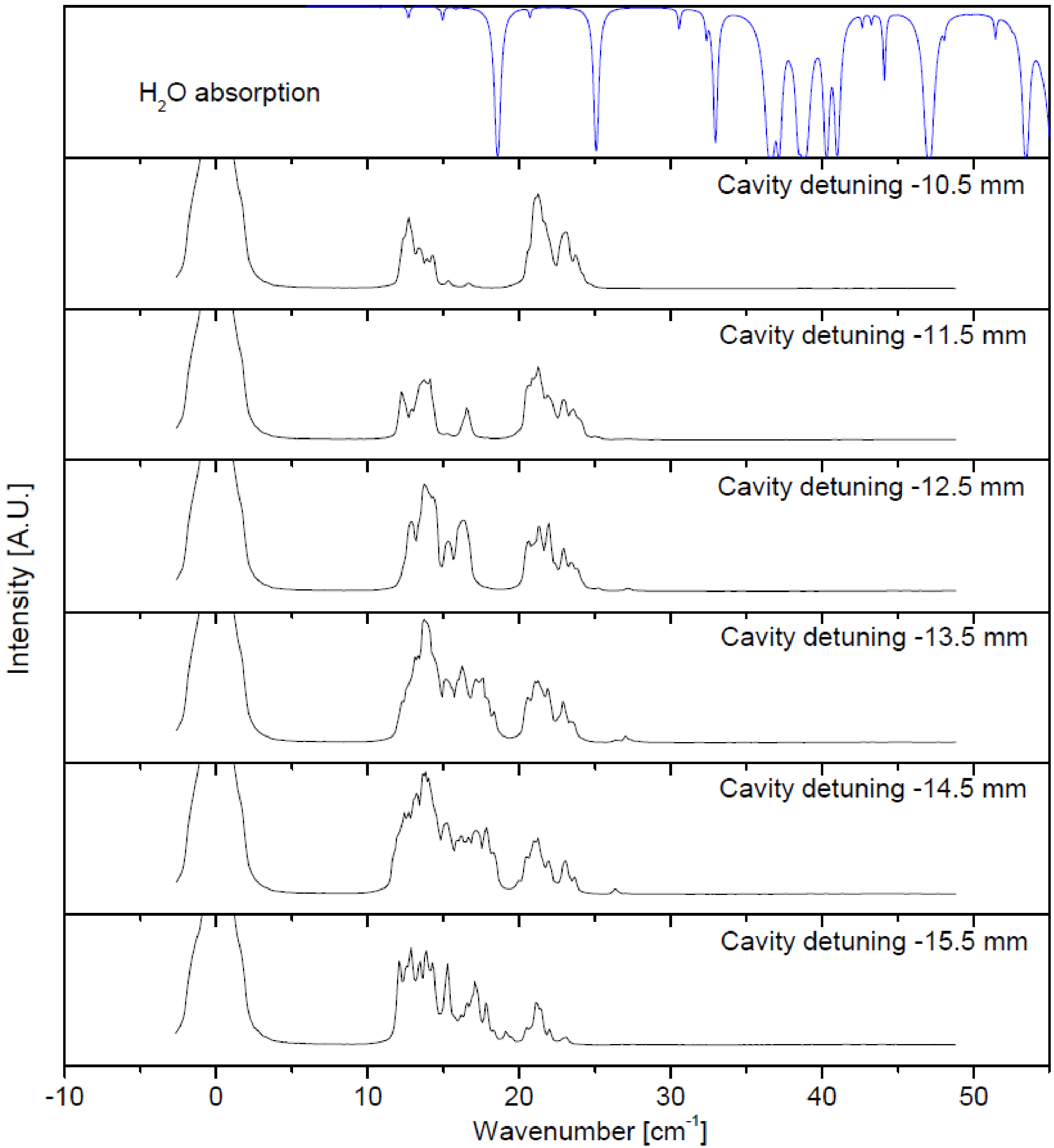
Upconversion scheme



Upconversion results





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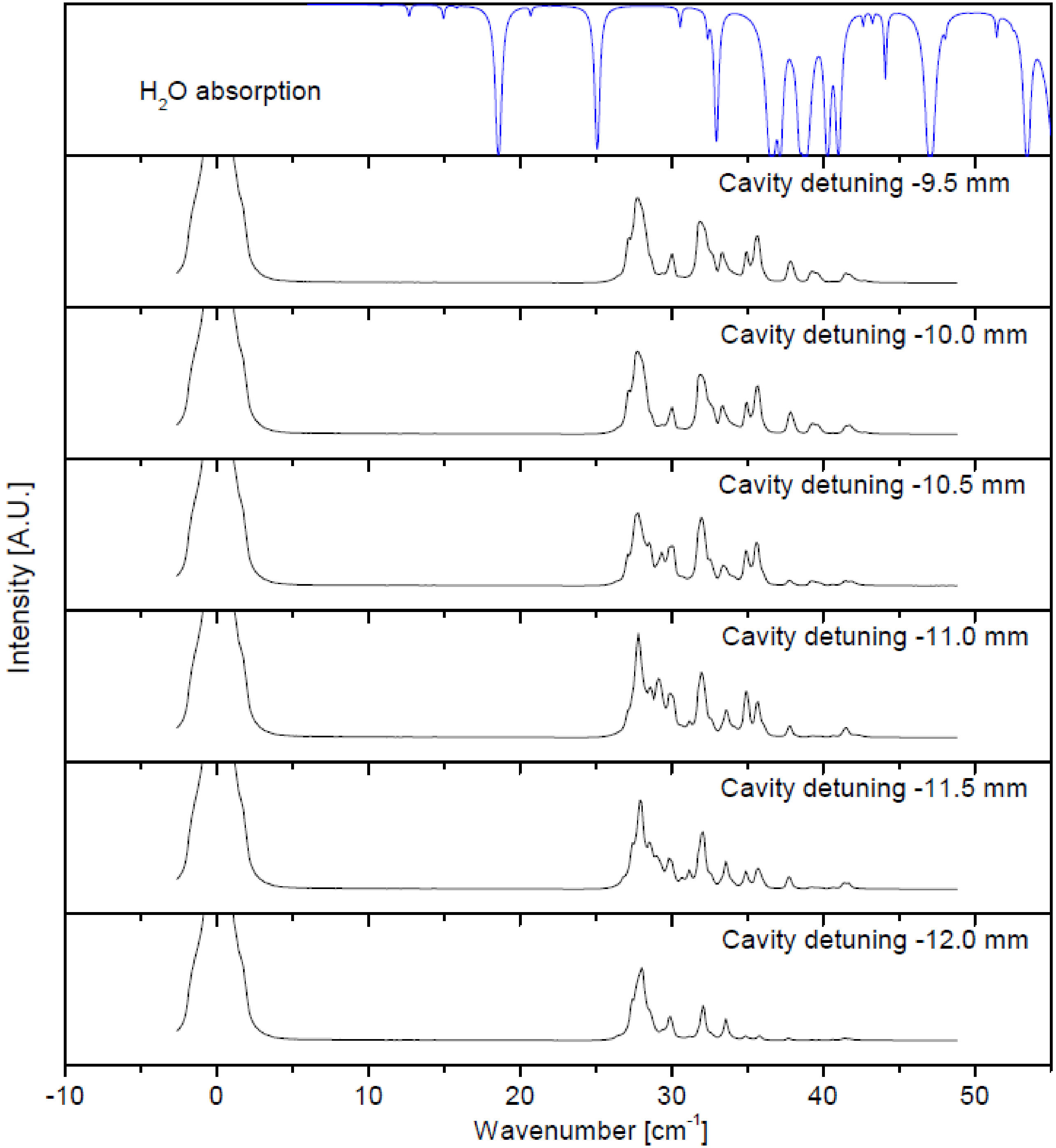
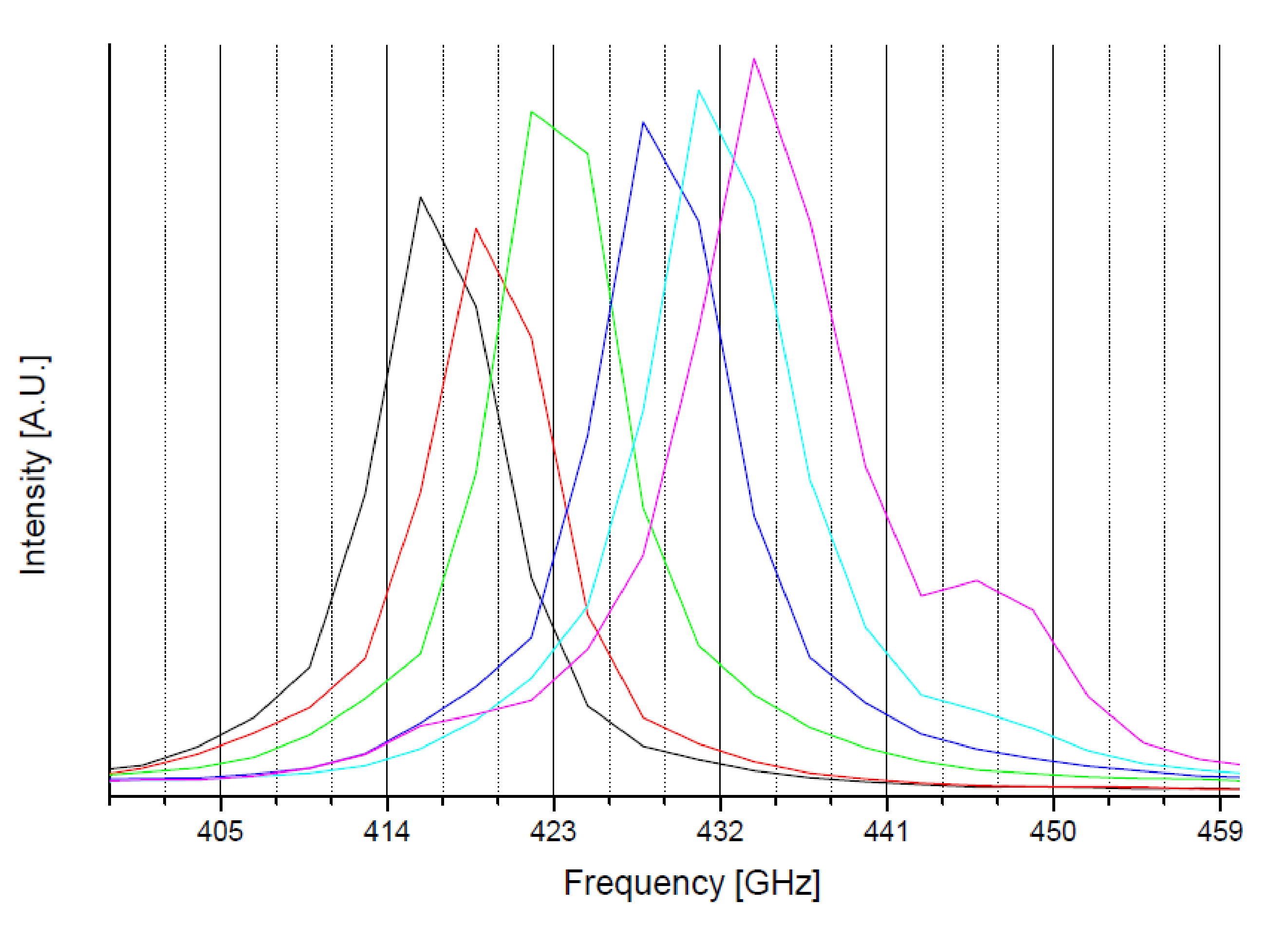


H2O absorption
Cavity detuning -9.5 mm
Cavity detuning -10.0 mm
Cavity detuning -10.5 mm
Cavity detuning -11.0 mm
Cavity detuning -11.5 mm
Cavity detuning -12.0 mm
Intensity [A.U.]
-10
0
10
20
30
40
50
Wavenumber [cm-1]

Spontaneous coherence



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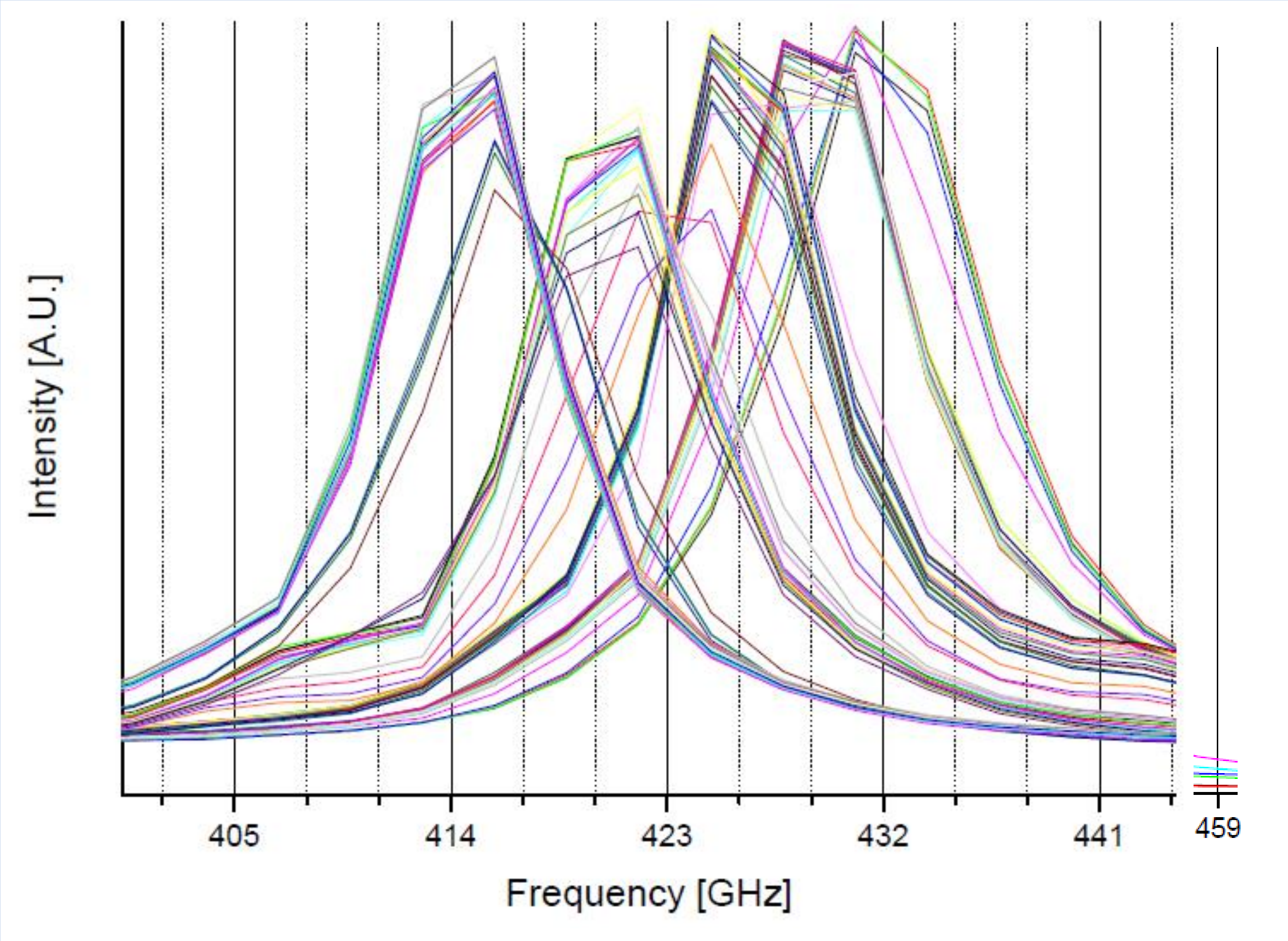
Spontaneous coherence



FLARE applications

- **Magneto-optical Spectroscopy**
  - ESR & ECR frequencies move towards THz
  - e-, lattice vibrations, polarons and SC band gaps spectroscopy
  - saturation spectroscopy and coherent THz photon-echo spectroscopy
- **Dynamics and Spectroscopy of Charge Carriers**
  - Transport in confined systems (quantum dots)
  - **Pump-probe experiments** in high magnetic fields
- **Optical-THz-NMR experiments**
  - **NMR sensitivity enhancement** by hyperpolarized nuclei
  - ***Need for powerful (CW) source***
  - FLARE may contribute to DNP

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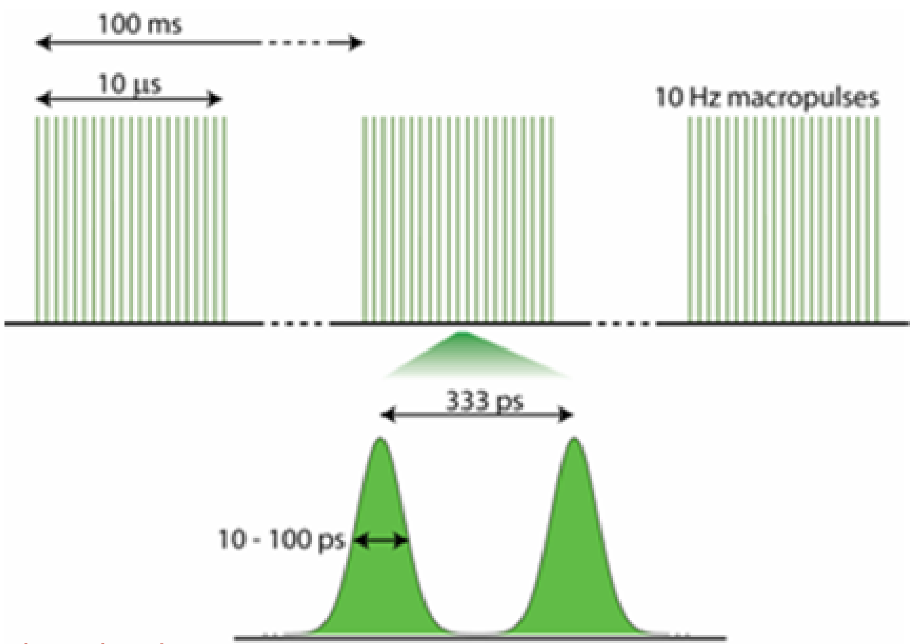
FLARE specifications

Pump-probe mode

- Spectral resolution 0.5 - 2% (10 - 100 ps)
- Power >100 kWatt / 10 kW



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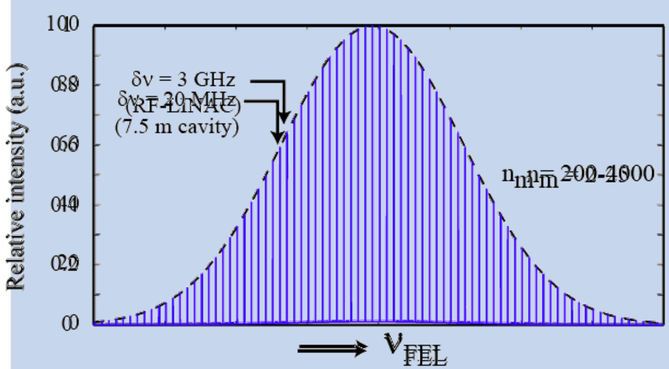
FLARE specifications

Pump-probe mode

- Spectral resolution — 0.5 - 2% (10 - 100 ps)
- Power — >100 kWatt / 10 kW

Spectroscopic mode

- Spectral resolution — 10^{-6} - 10^{-5} (10 µs)
- Power — 50 Watt



FLARE specifications

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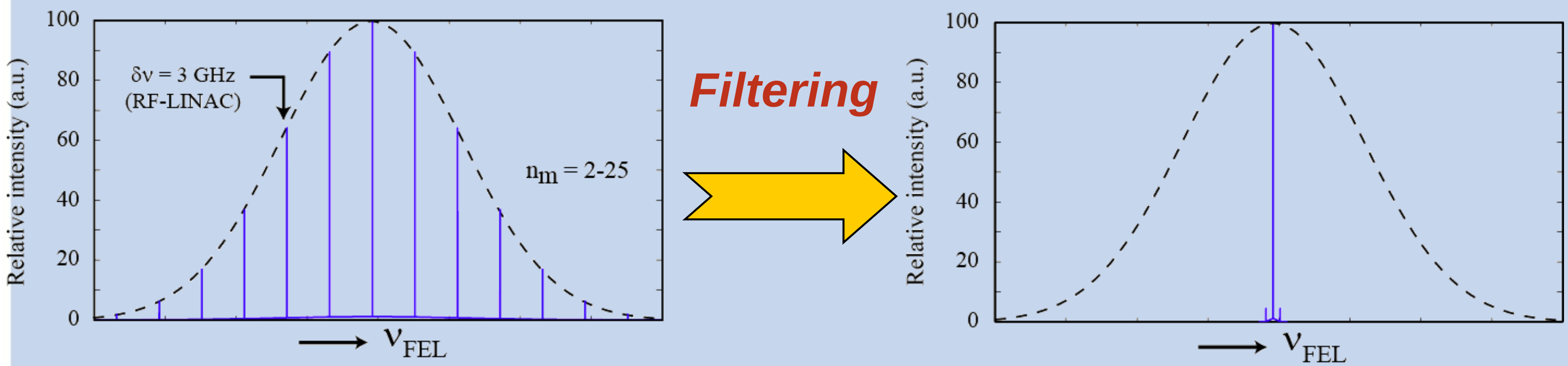

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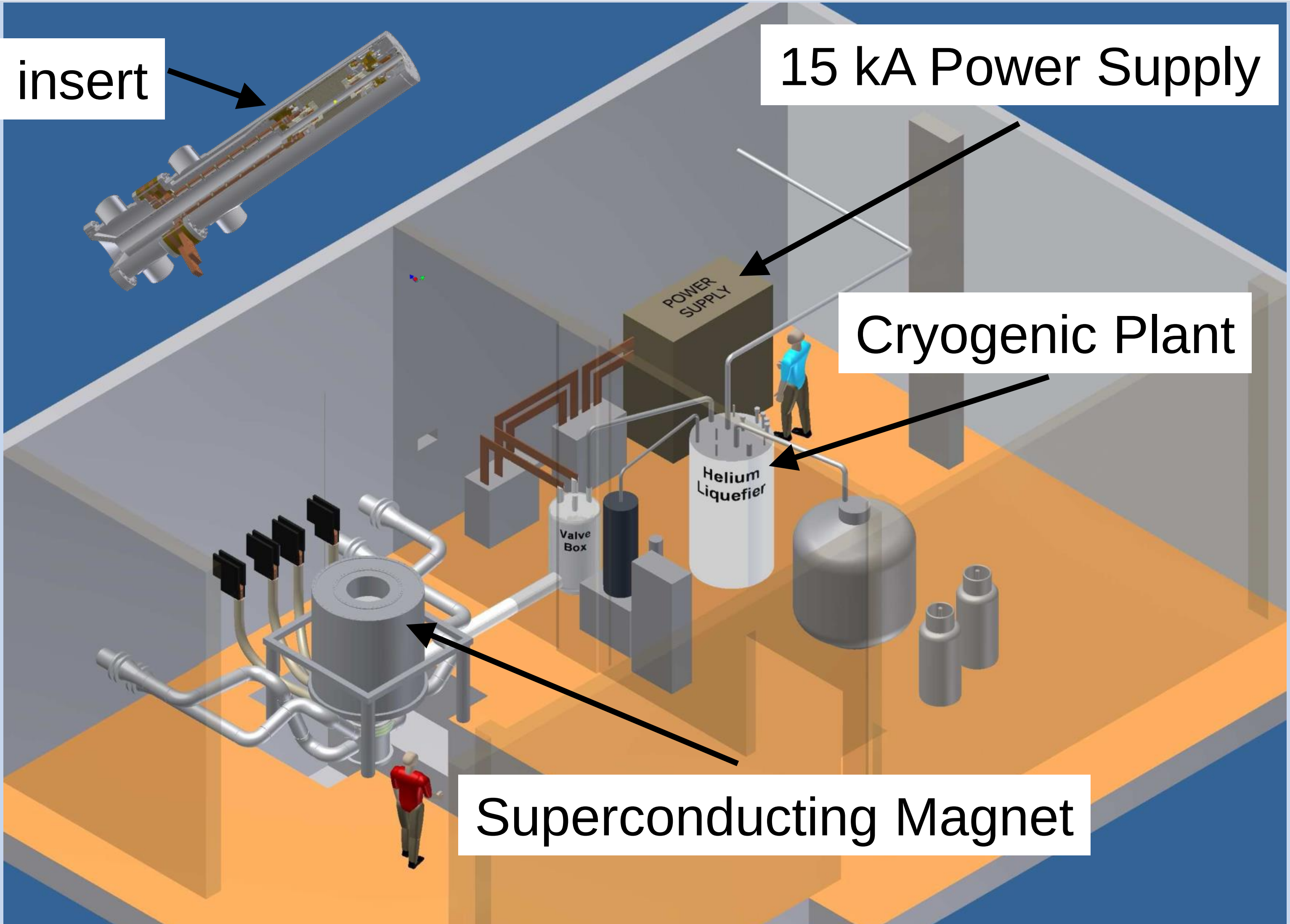
45 T Hybrid magnet (2014)



Thank you for your attention!

Summary of FLARE specs

Pump-probe mode (1% bandwidth)

	Units	λ=100 μm	λ=1500 μm
Micropulse energy	μJ	3	
Macropulse energy	mJ	60	
Macropulse avg. power	kW	8	
Avg. power	W	0.6	
Micropulse length	Psec	10	100
Absolute Bandwidth	cm^{-1}	1	0.06
Peak power in micropulse	Watt	$4\ 10^5$	$6\ 10^3$
Power density	Watt cm^{-2}	$5\ 10^7$	$2\ 10^5$
Max Electric Field	V cm^{-1}	$3\ 10^5$	$5\ 10^4$
Ponderomotive energy	eV	150	$2.5\ 10^3$

Spectroscopic mode

	Unit	λ=100 μm	λ=1500 μm
Absolute Bandwidth	MHz	0.1	0.1
Relative Bandwidth	%	$3\ 10^{-9}$	$5.\ 10^{-8}$
Power during macropulse	Watt	50	400
Power density	Watt cm^{-2}	10^4	$4\ 10^2$

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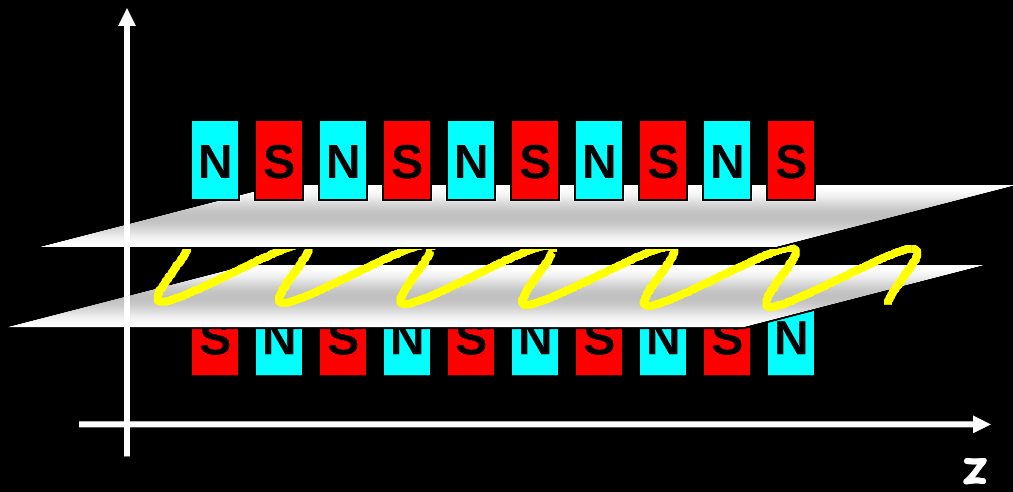
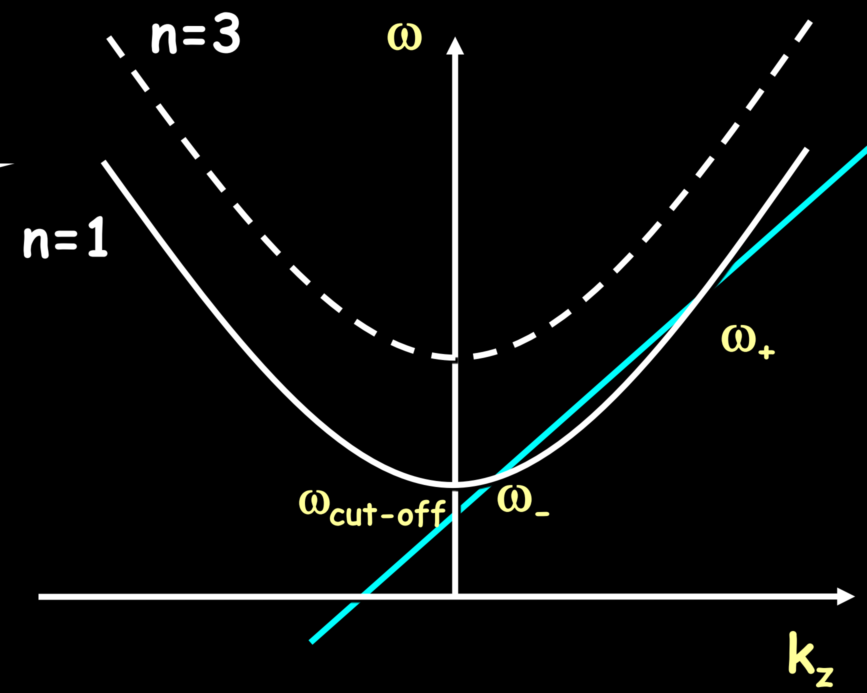
Long wavelength FELs





$$\omega = v_z(k_z + k)$$

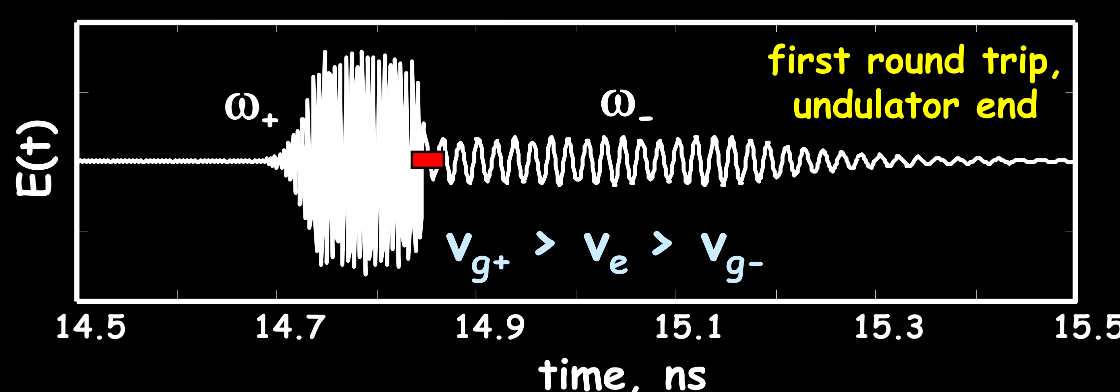
FEL resonant condition

Waveguide dispersion:

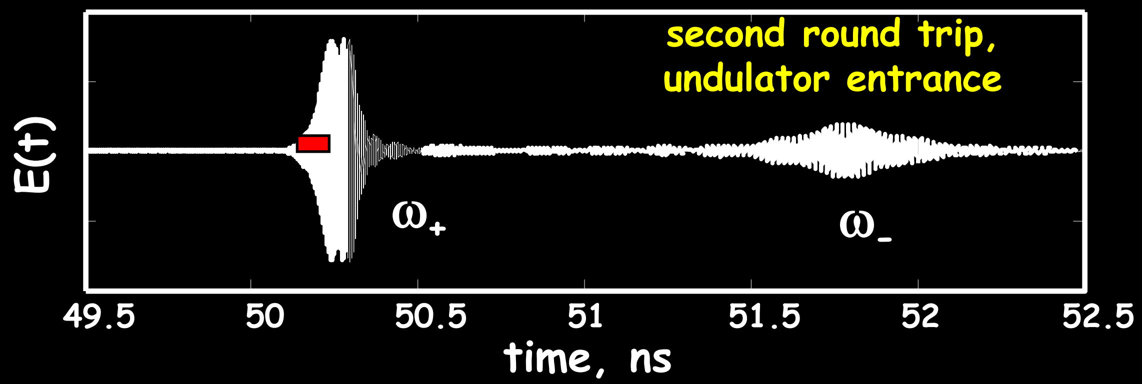
$$k_z^2 = \frac{\omega^2}{c^2} - \frac{(n\pi)^2}{g^2}$$

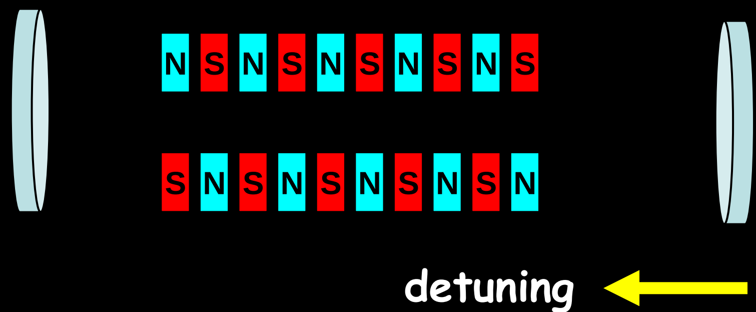
Group velocity:

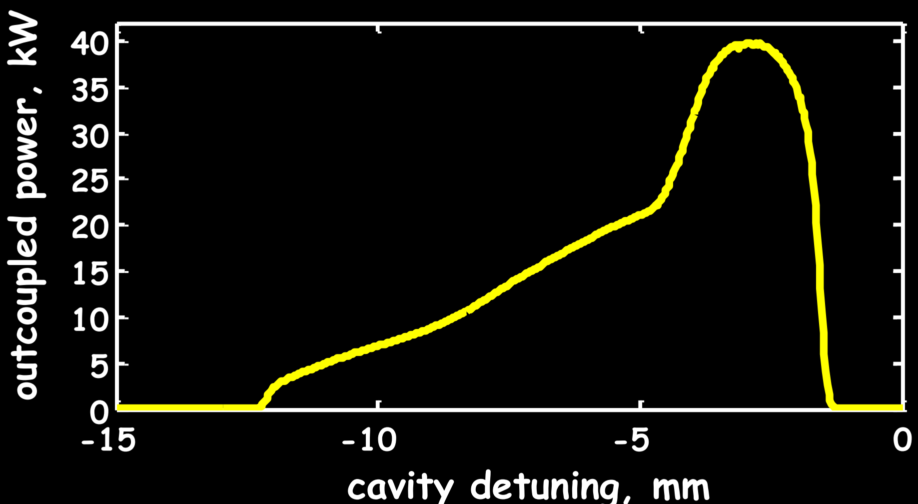
$$v_g = \frac{d\omega}{dk_z} < c$$



Results (FLARE is conventional FEL)

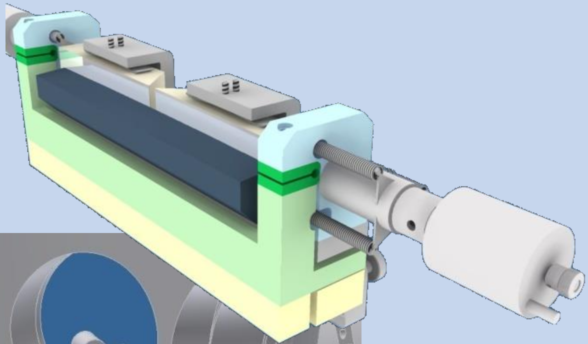


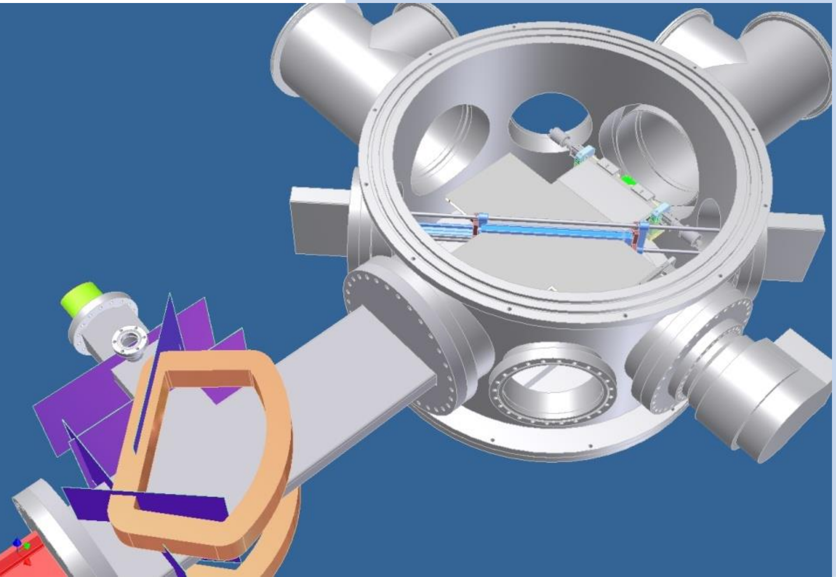


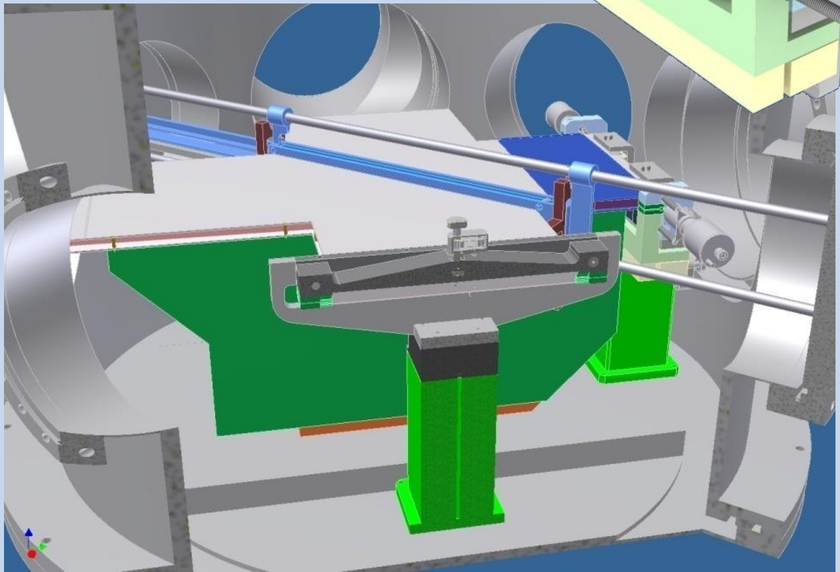


Downstream mirror

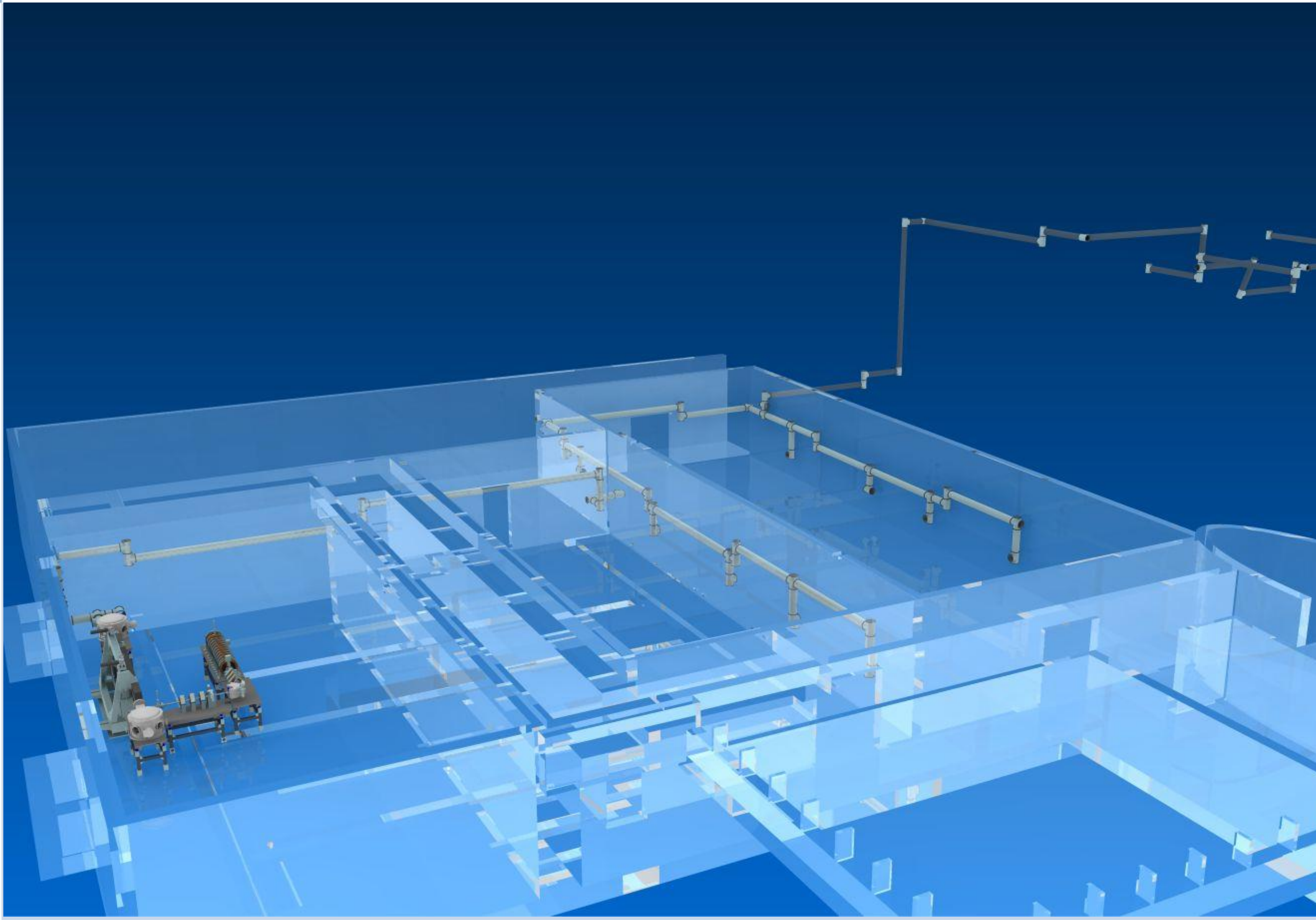
- Adjustable **outcoupling slit** (hole coupling)
- Close to first mirror of optical distribution system
- Future implementation **Michelson interferometer** (removable beam-splitter)







Optical distribution



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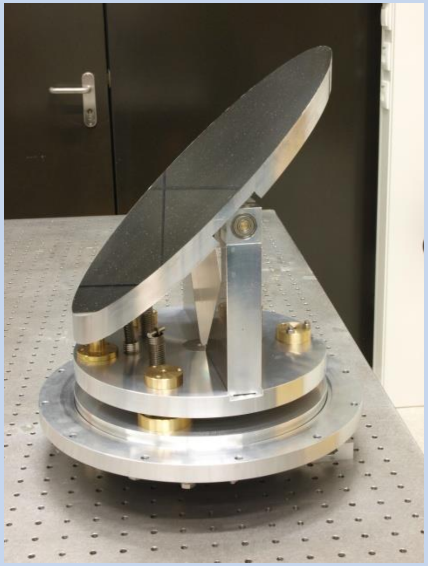
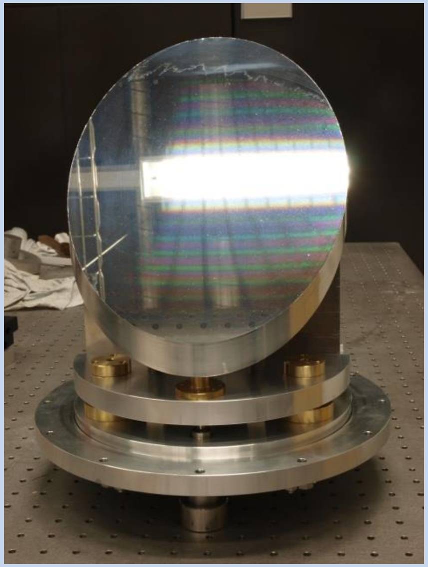
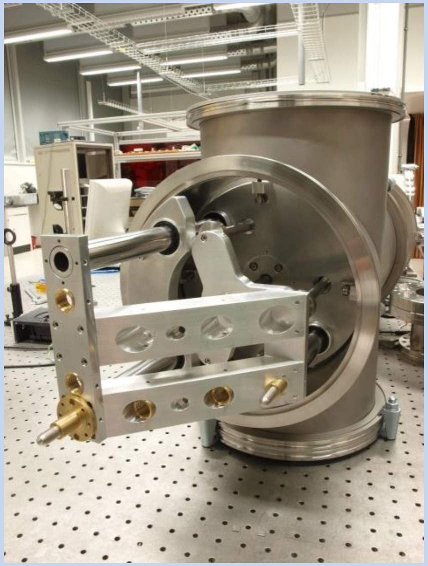
Optical distribution

- **LARGE system** (HZDR / RU design)
  - 250 mm diameter tubing / mirrors
  - 150 m after full realization
  - Refocusing every 8-10 m
  - First part completed and tested

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