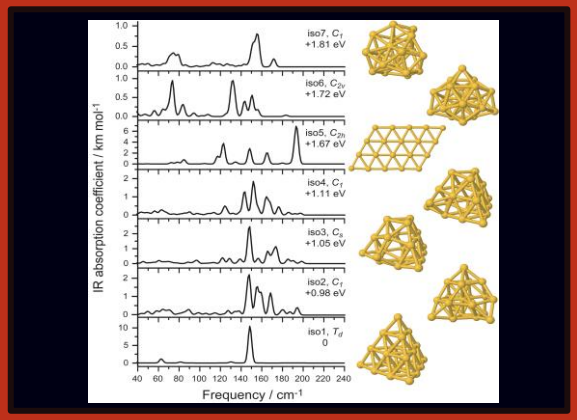
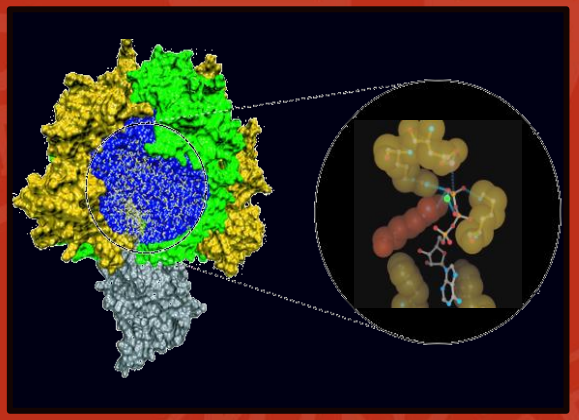
The infrared and THz user facility FELIX in Nijmegen





Britta Redlich
on behalf of the FELIX team

FEL Conference 2012, Nara, Japan – 29 August 2012

FELIX on the move – start 15 March 2012






From Nieuwegein to Nijmegen

Note about scaling

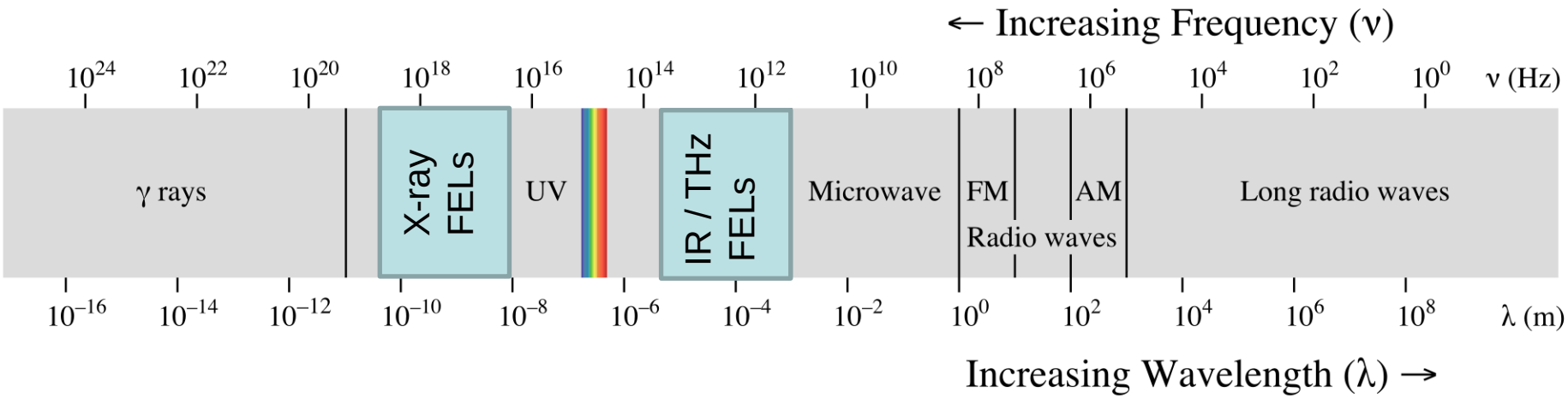
The storybook

Town Musicians of Bremen

Rooster	FLARE
Cat	FELIX-FEL1
Dog	FELIX-FEL2
Donkey	FELICE

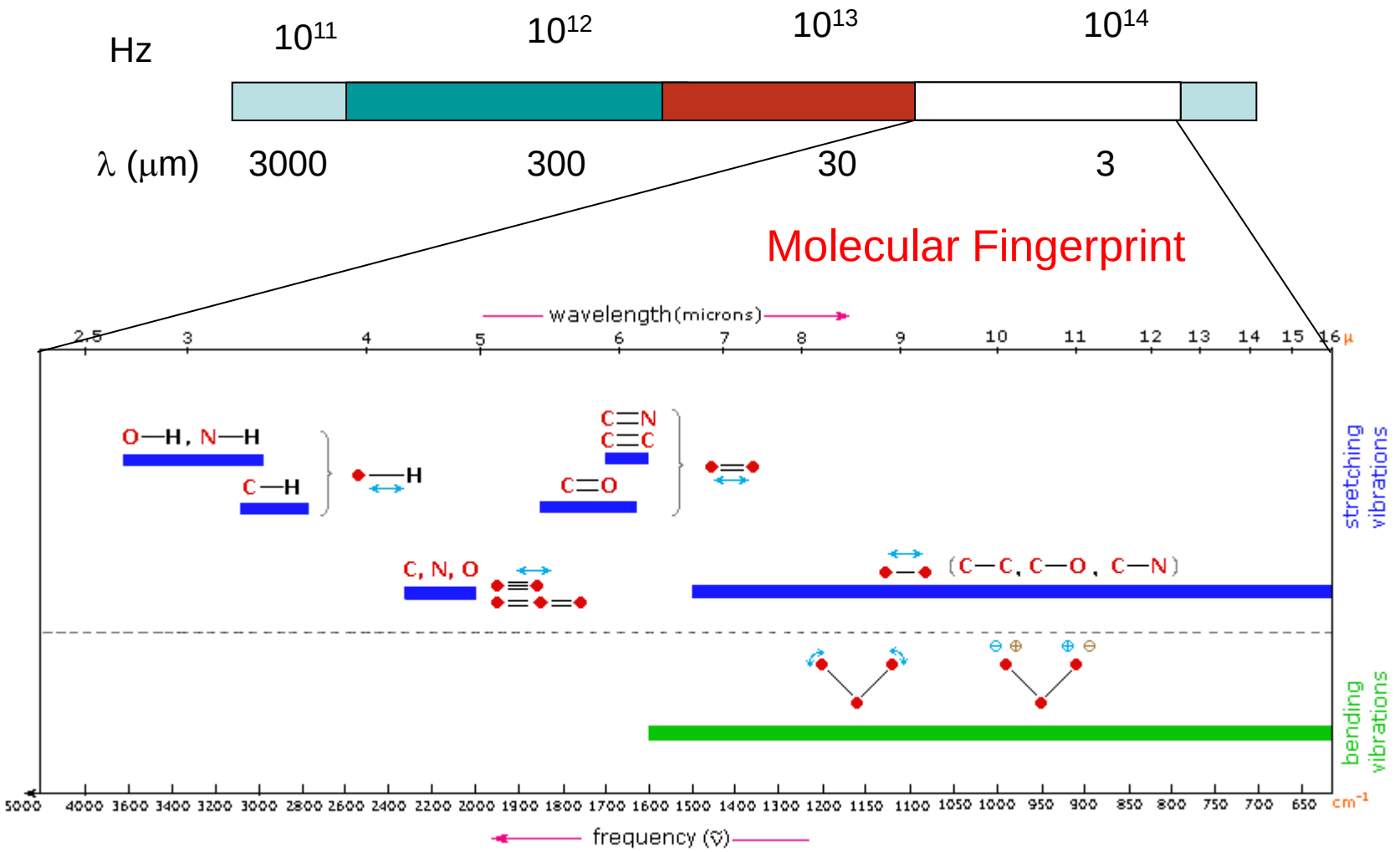
The infrared and THz user facility
FELIX Facility @ Nijmegen

Why is the IR / terahertz region interesting?

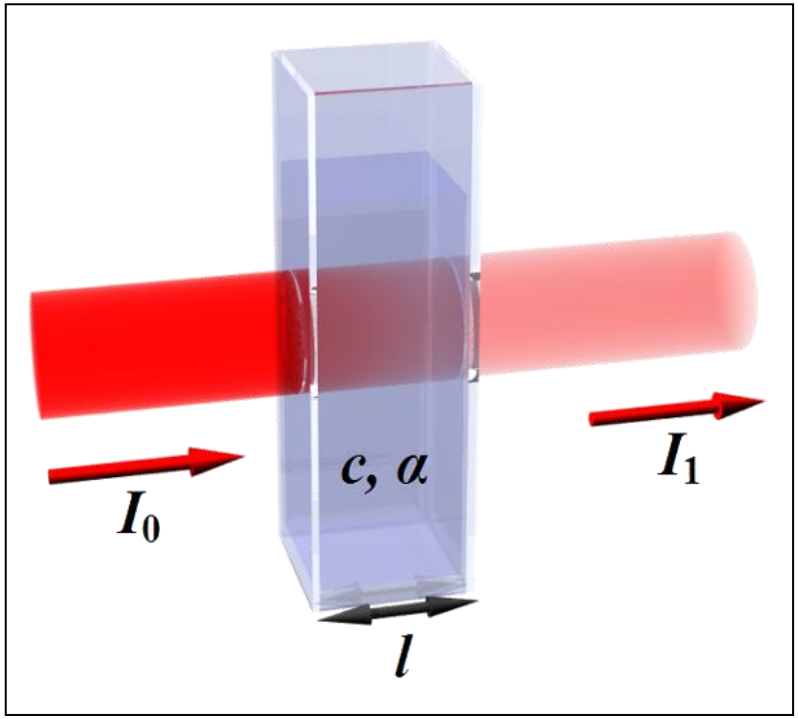


1 THz –1 psec – 300 μm – 33 cm^{-1} – 4.1 meV – 47.6 K – 0.39 kJ/mol – 0.094 kcal/mol

The fingerprint region



Classical spectroscopy

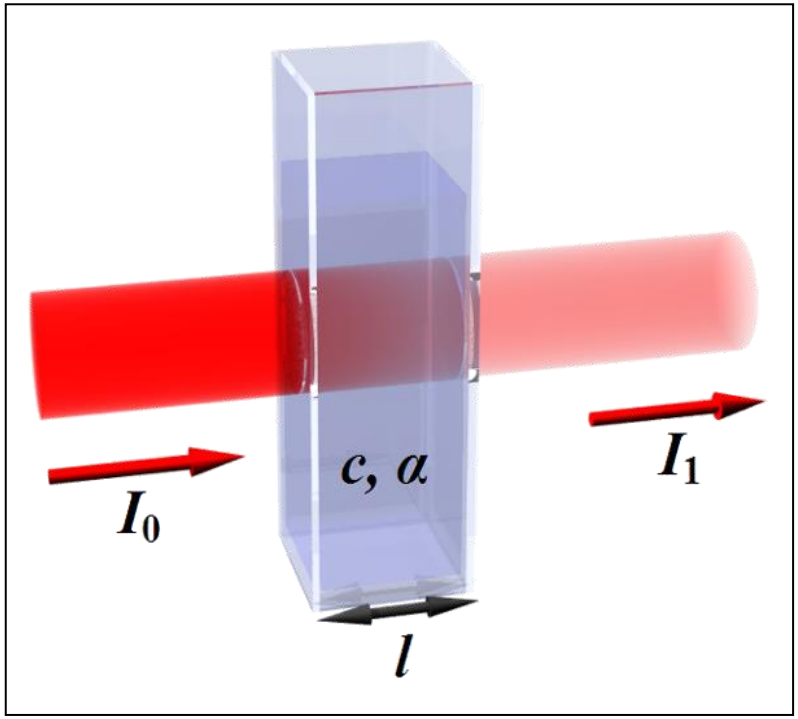


almost every lab has an (FT)IR spectrometer

because IR can do:

- identification
- structure
- geometry
- quantitative analysis
- .....

Restrictions



almost every lab has an (FT)IR spectrometer

because IR can do:

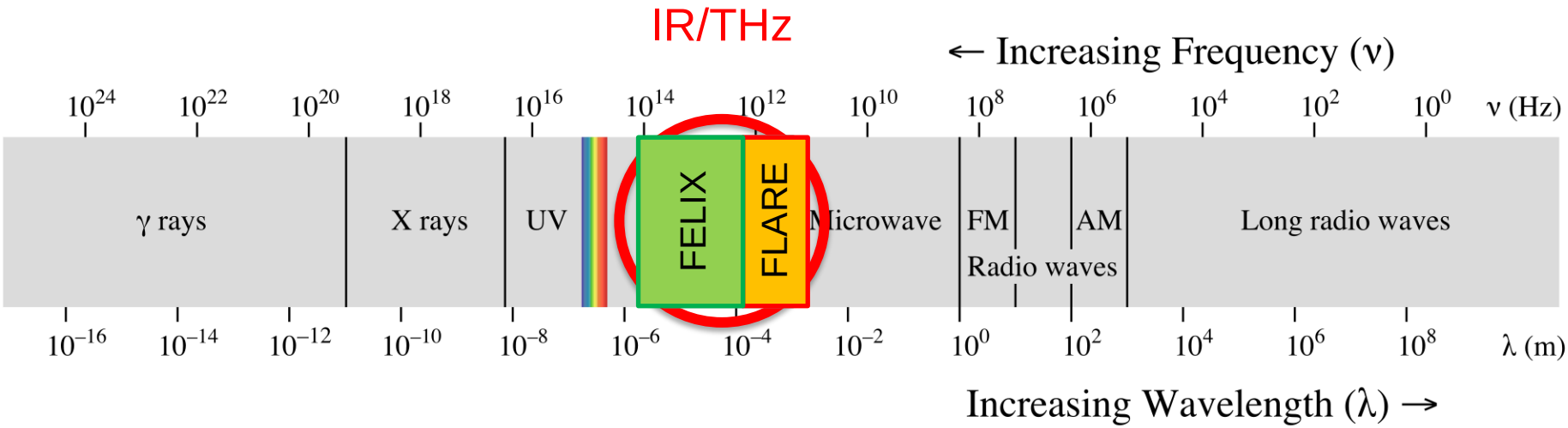
- identification
- structure
- geometry
- quantitative analysis
- .....

but:

"Classical" spectroscopy: Requires optical depth (10^{-3})

➔ selected experiments

Why is the IR / terahertz region interesting?



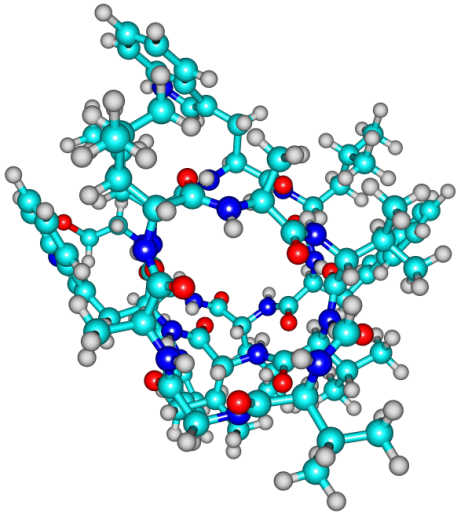
Why is the IR / terahertz region interesting?

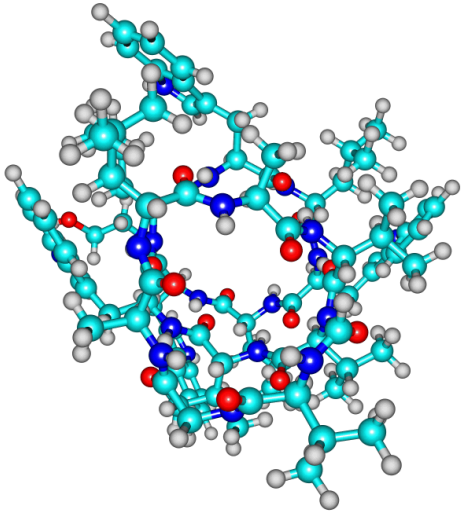
IR /THz spectroscopy

FELIX **FLARE**

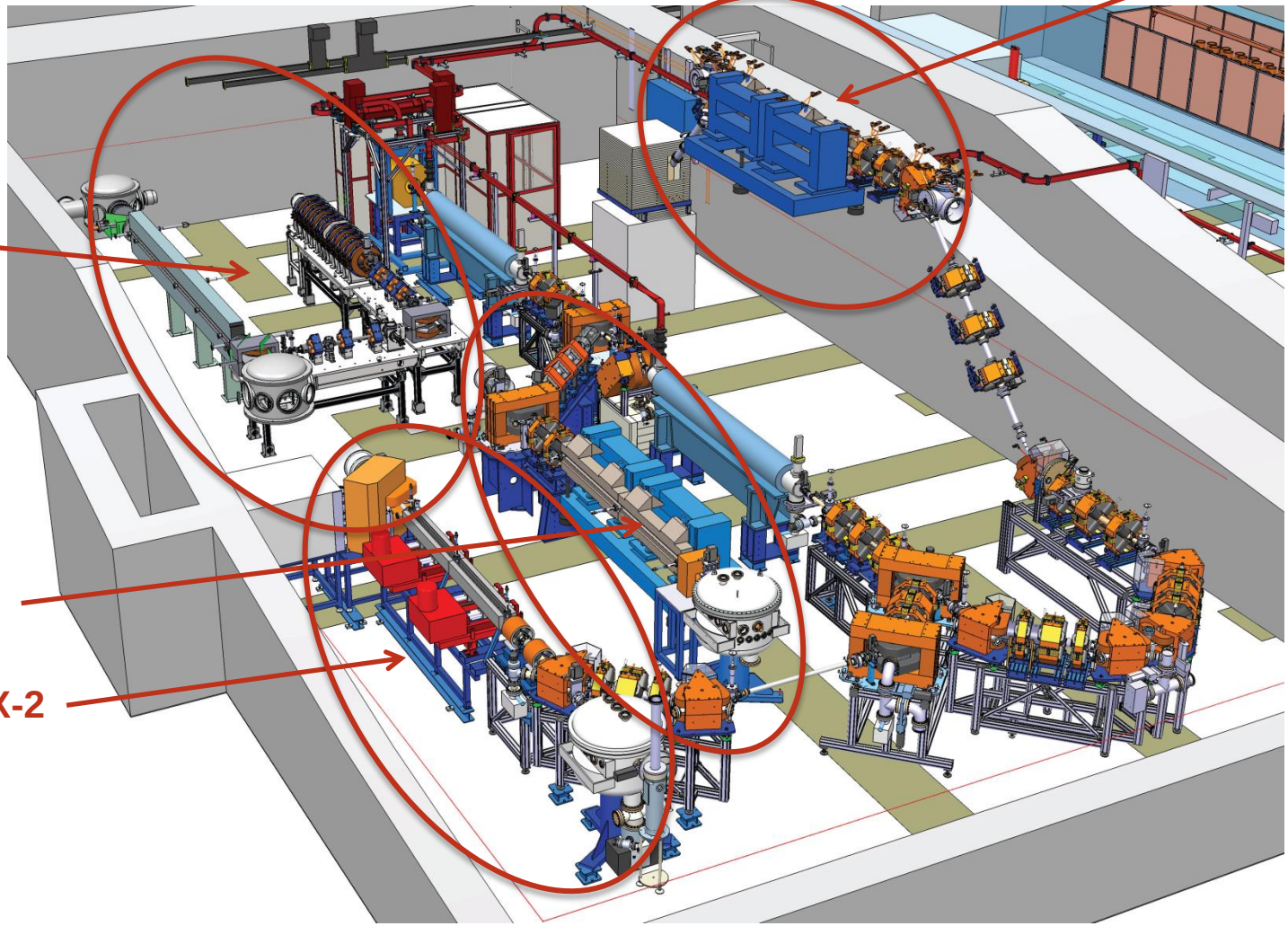
mid-IR **far-IR**

local modes global modes

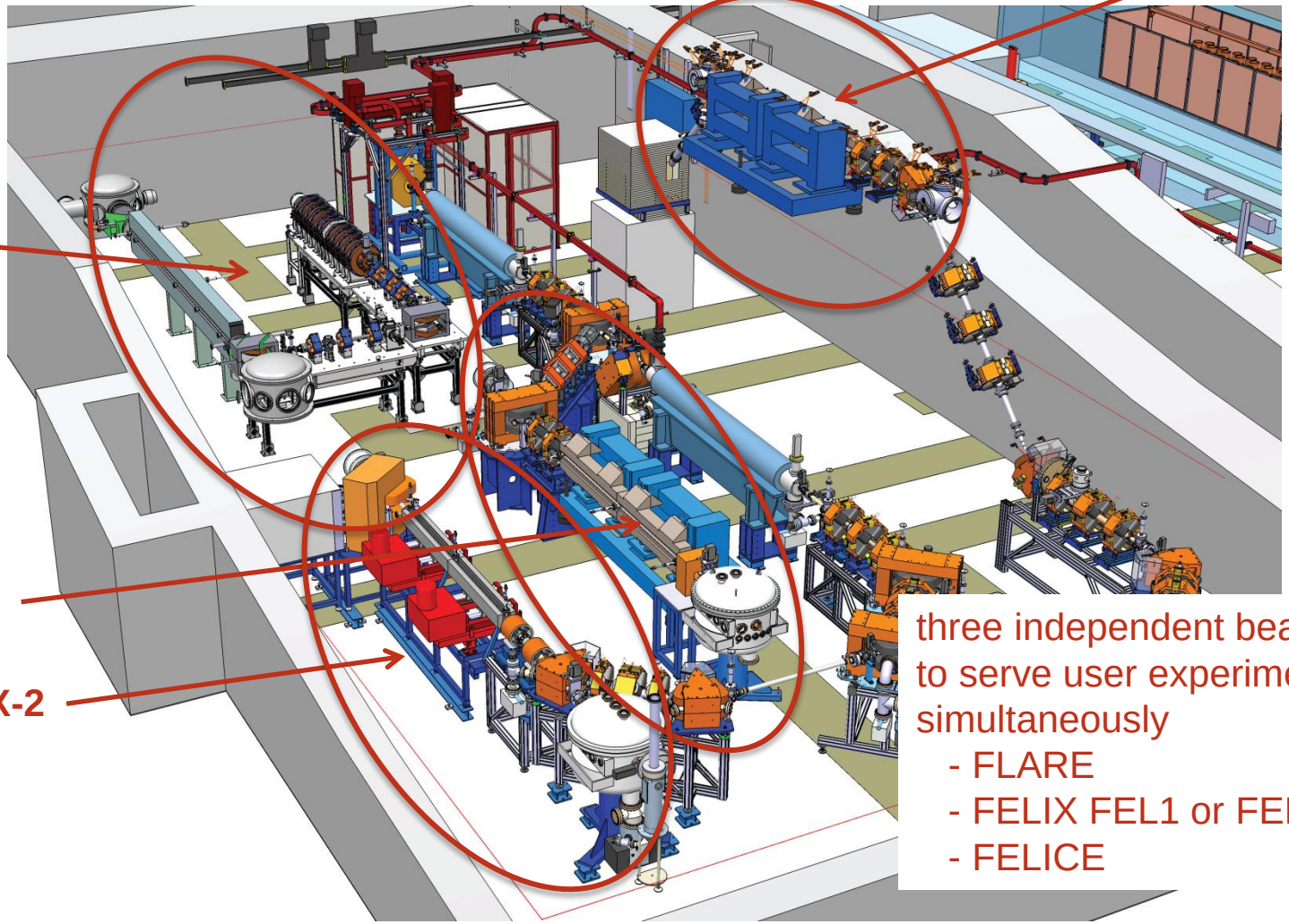




FELIX facility: Infrared Sources



FELIX facility: Infrared Sources



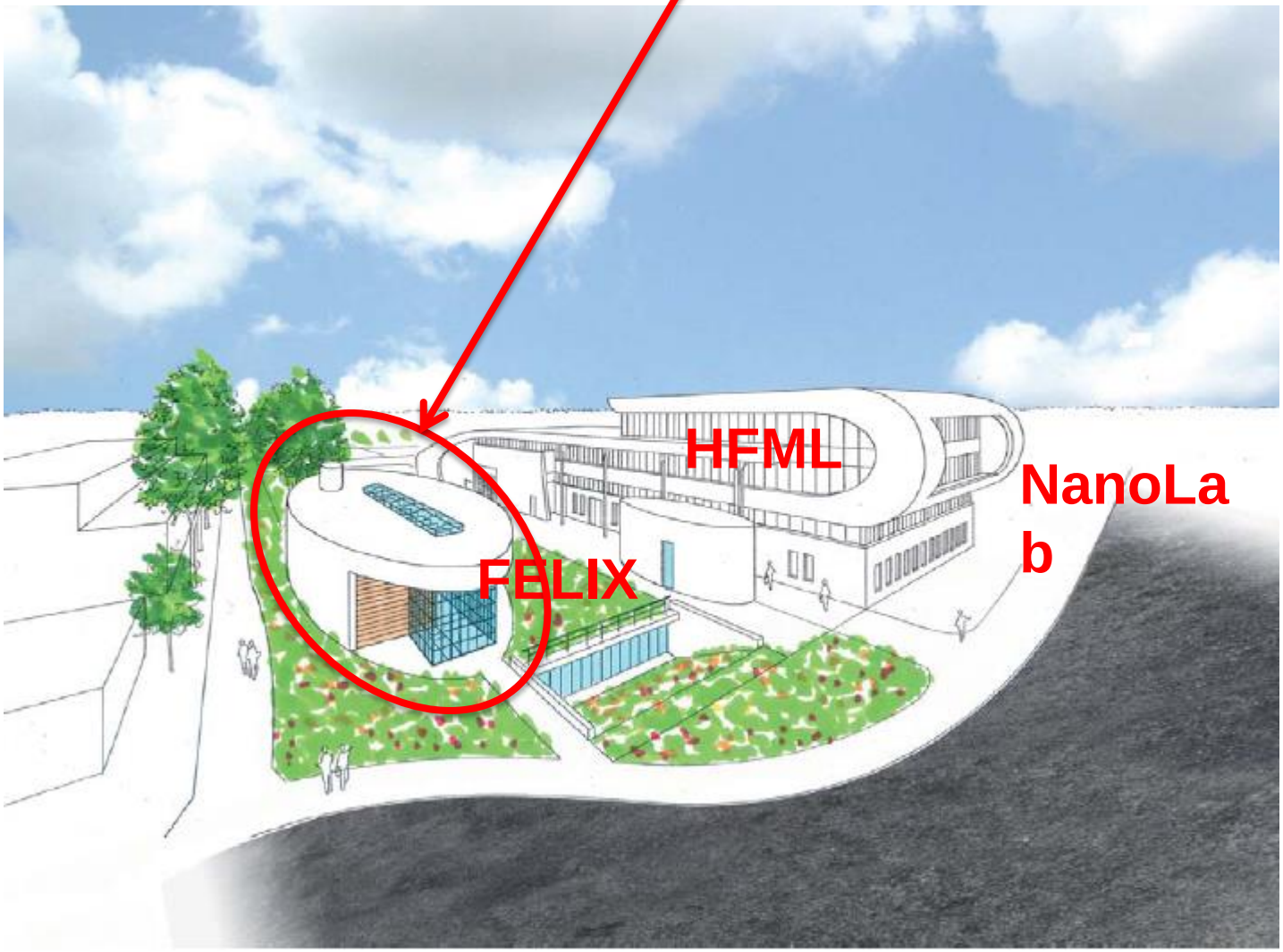
three independent beamlines to serve user experiments simultaneously

- FLARE
- FELIX FEL1 or FEL2
- FELICE

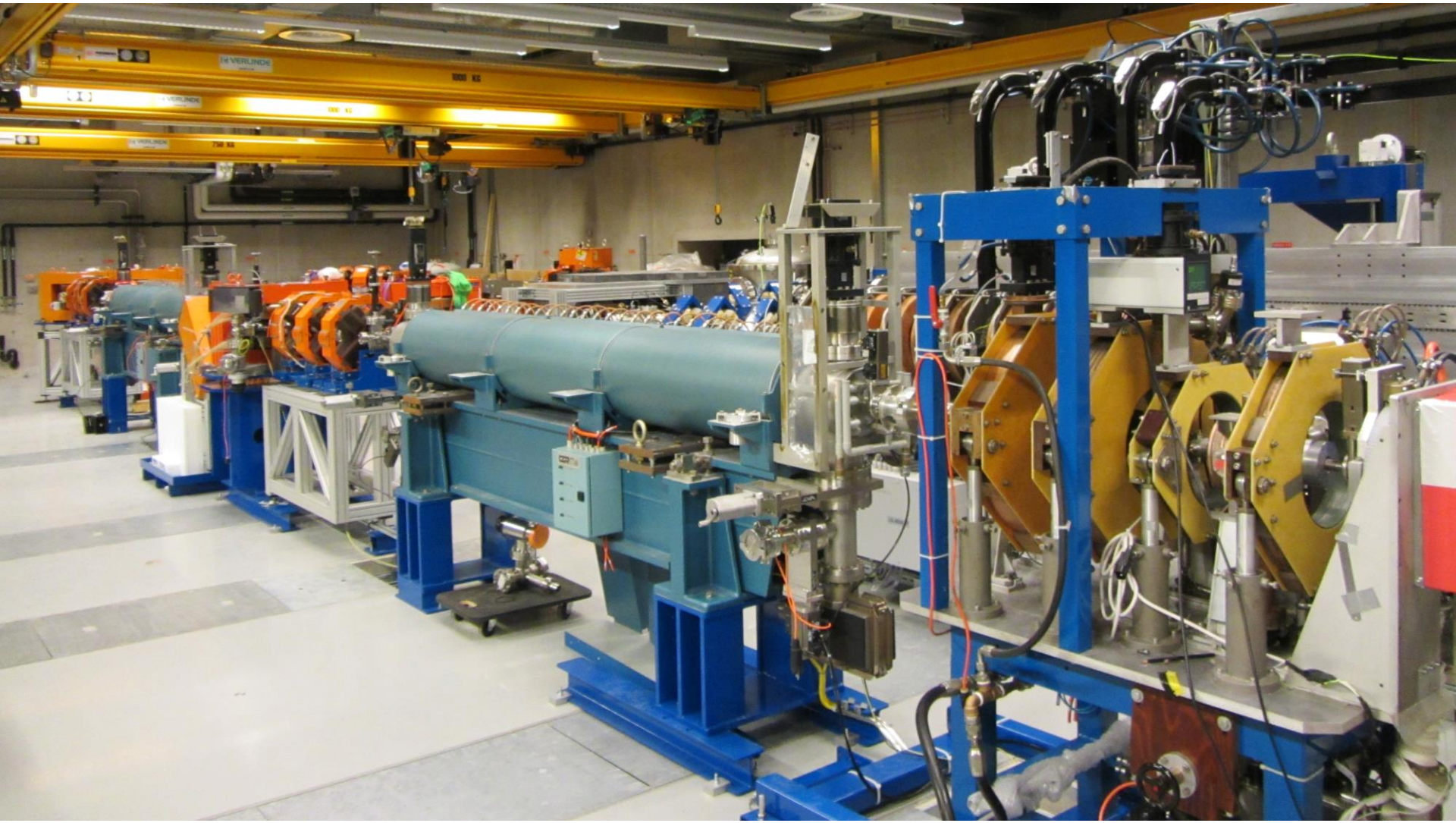
FELIX Facility: Specs of the Infrared Sources

SPECS:	FELIX:	FLARE:	FELICE:
e-beam energy	50/45 – 15 MeV	15 – 10 MeV	50/45 – 18 MeV
spectral range	2.7 - 150 micron	100 - 1500 micron	5 - 100 micron
	3600 - 66 cm^{-1}	100 - 6 cm^{-1}	2000 - 100 cm^{-1}
	120 - 2 THz	3 – 0.25 THz	60 - 3 THz
	450 - 8 meV	12 – 0.75 meV	250 - 12 meV
pulse structure	micro / macropulse	micro / macropulse	micro / macropulse
rep. rate	25 MHz/1 GHz@10 Hz	3 GHz/20 MHz@10 Hz	16 MHz/1GHz@10 Hz
micropulse energy	1- 20 µJ	≈ 5 µJ	max. 1 mJ
macropulse energy	≤ 100 mJ @ 1 GHz	≤ 100 mJ @ 1 GHz	max. 5 J @ 1 GHz
peak power	≤ 100 MW	≤ 10 MW	≤ 5 GW
polarisation	linear	linear	linear
spectral bandwidth (FWHM)	0.2 – 5%	≤ 1%*	0.4 – 3%
		* spectral mode ≤10^{-4}	
continuous tunability	200 – 300%	? %	200 – 300 %

FELIX facility @ Nijmegen

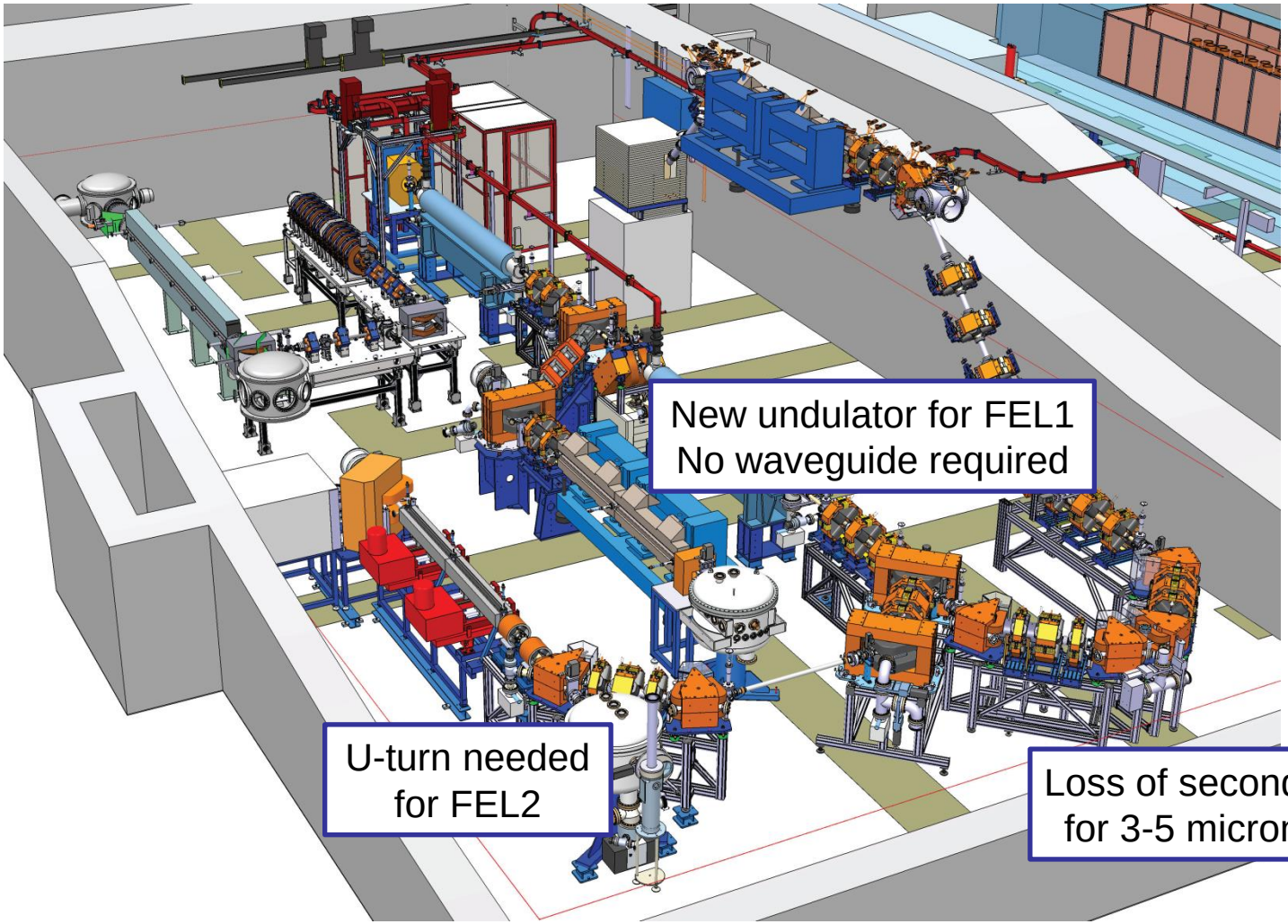


FELIX facility: Glimpse into the vault

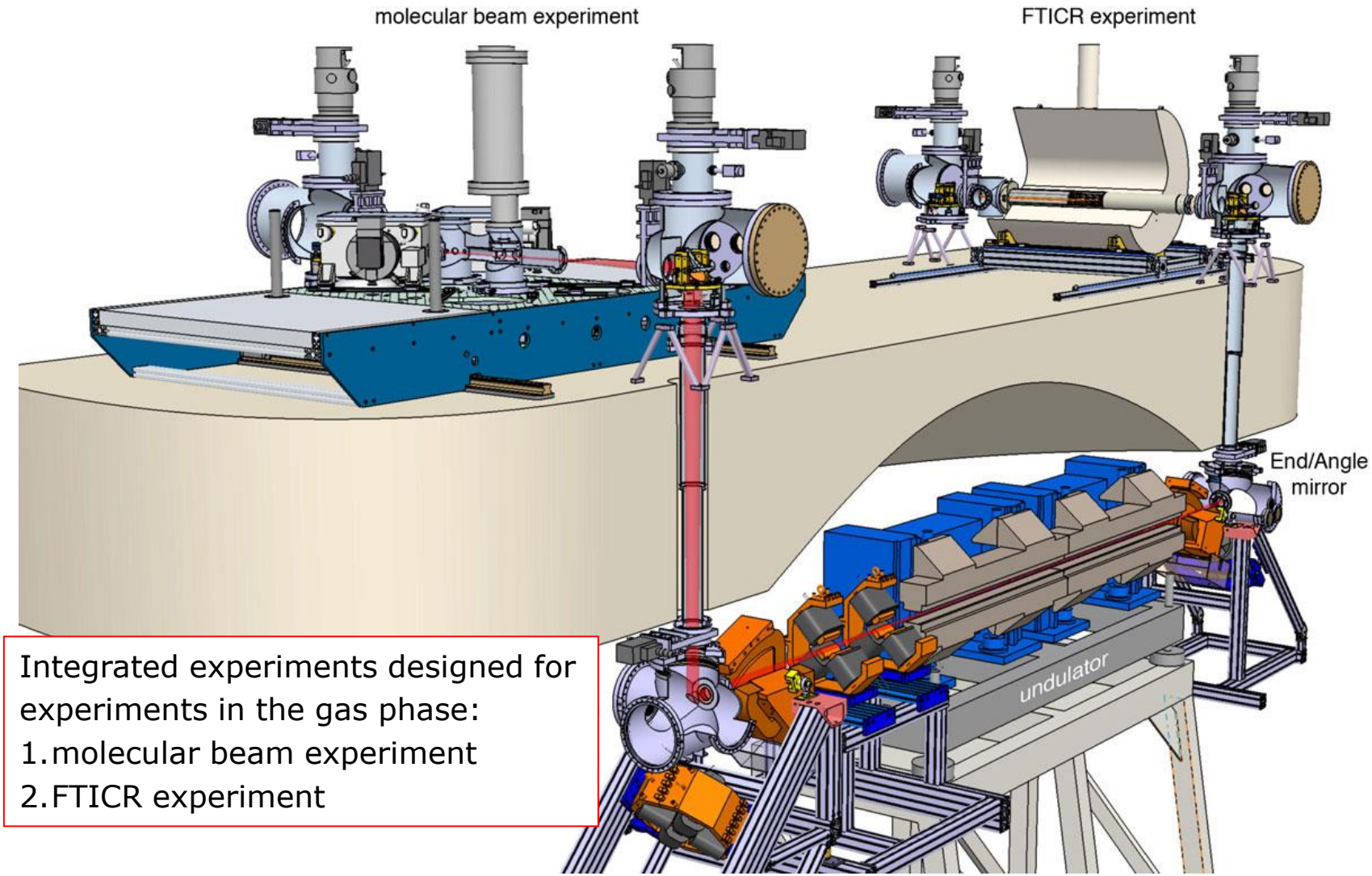


Anything new – anything special?

Changes to FELIX / FELICE



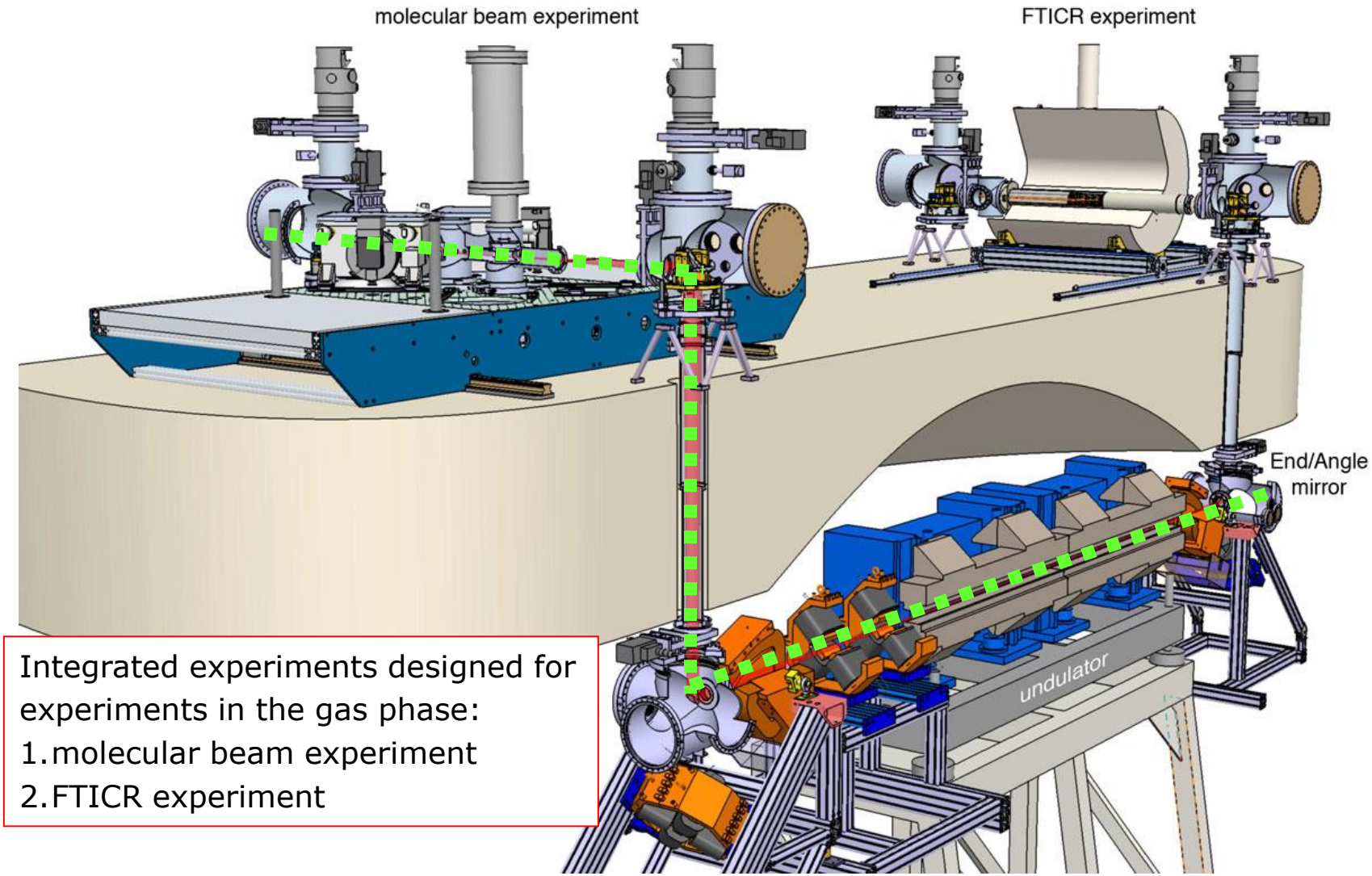
FELICE: intra-cavity experiment



Integrated experiments designed for experiments in the gas phase:

1. molecular beam experiment
2. FTICR experiment

FELICE: intra-cavity experiment



Integrated experiments designed for experiments in the gas phase:

1. molecular beam experiment
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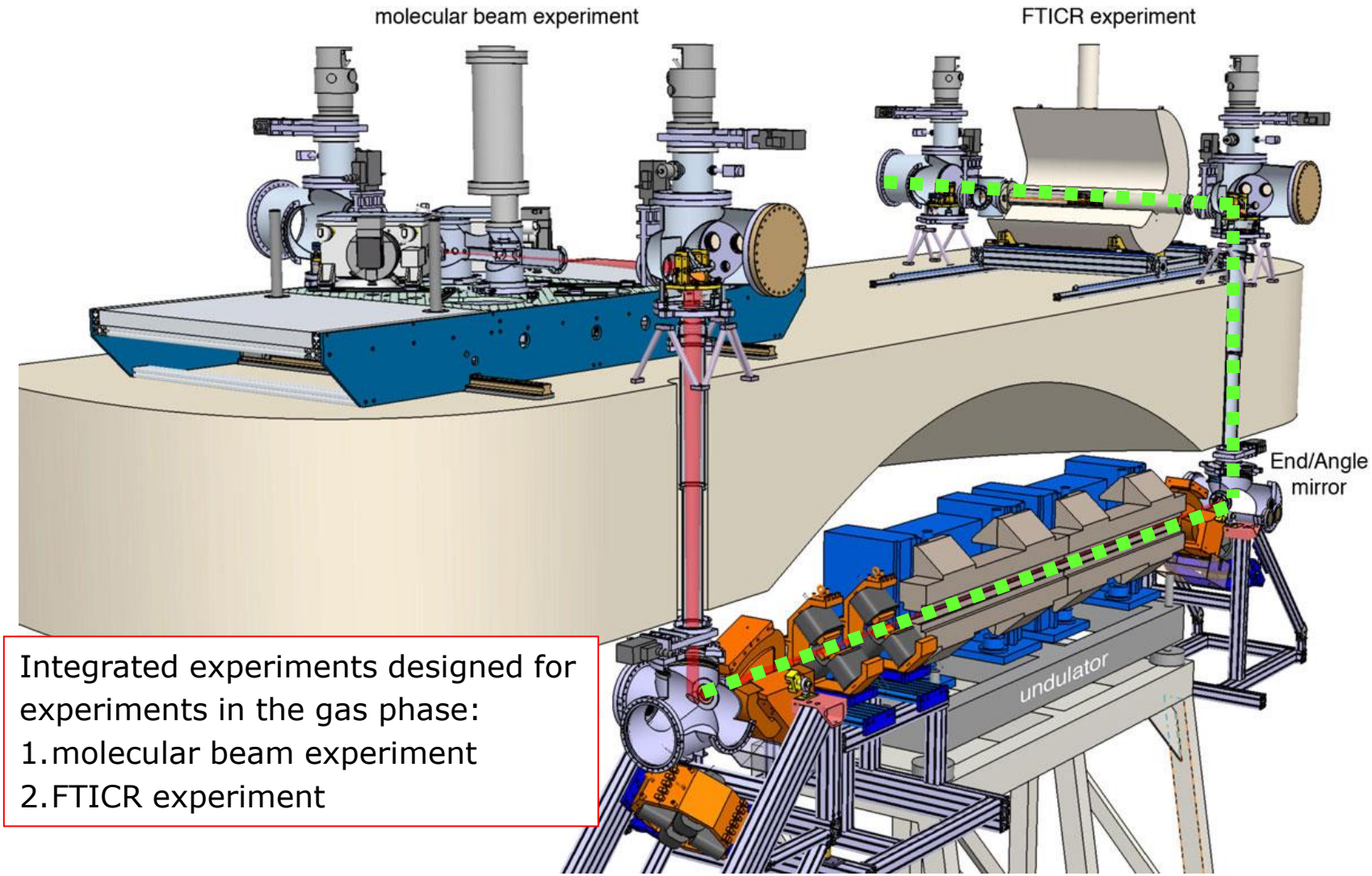
FELICE: intra-cavity experiment

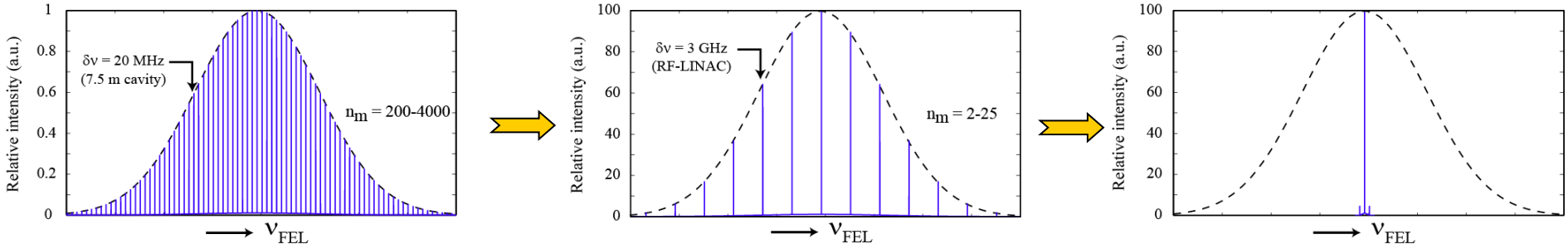


Integrated experiments designed for experiments in the gas phase:

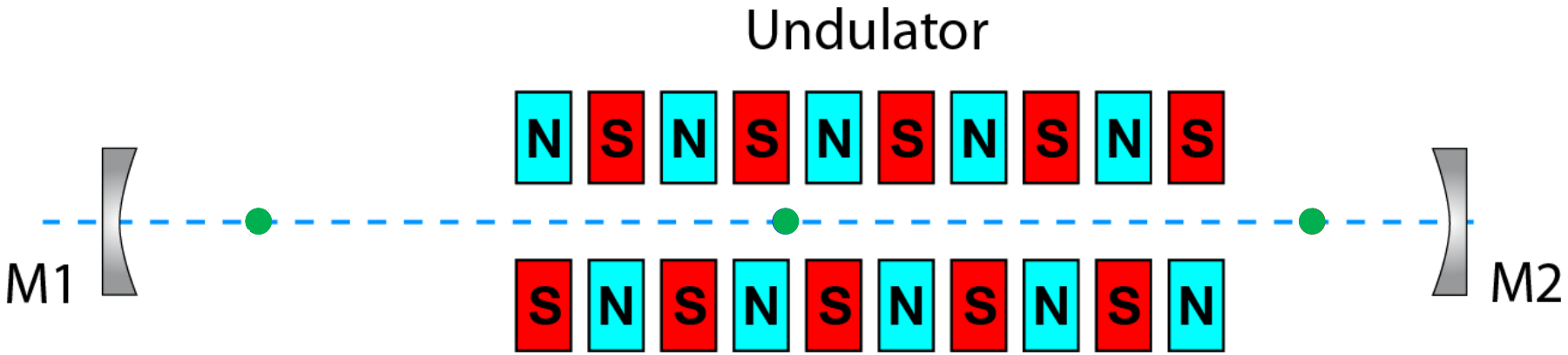
1. molecular beam experiment
2. FTICR experiment

FLARE: high-resolution spectroscopic mode

expected bandwidth: ≤ 10^{-4}
longest wavelength demonstrated: 70 μm



Demonstrated previously: Oepts and Colson *(1990)*, Bakker, Oepts, Van der Meer *et al. (1993),* Oepts, Weits, Van der Meer *et al.* (*1996-1998*), Szarmes, and Madey (*1993*)



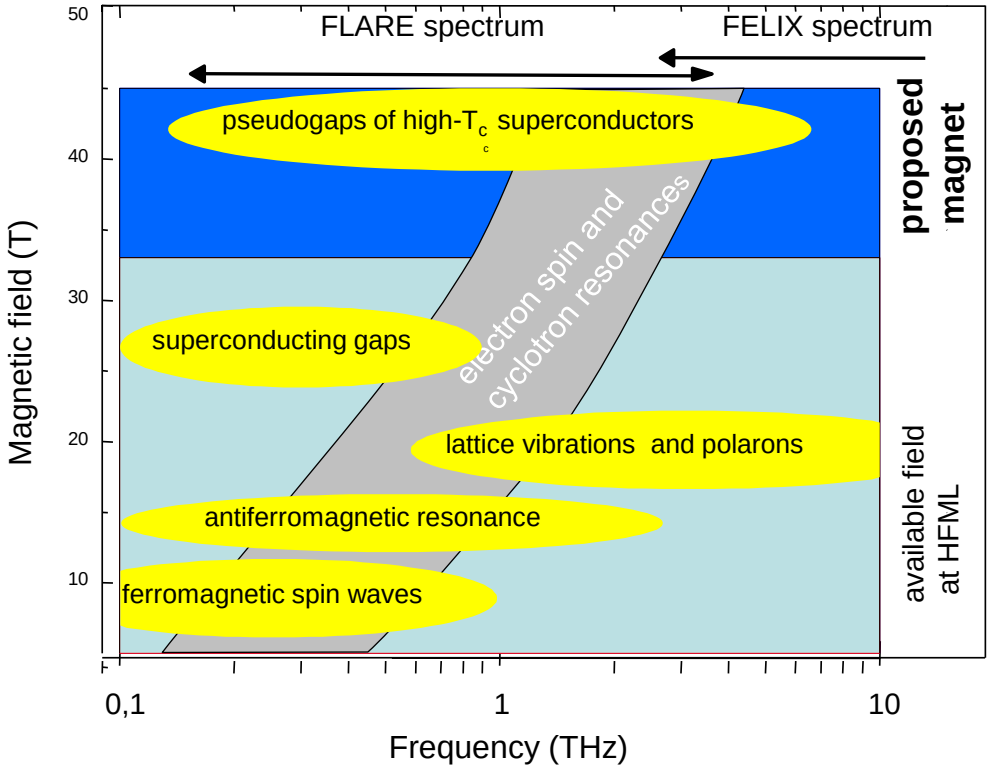
The neighbour: HFML

The Frog That Learned to Fly

(see A. Geim, Physics Today, September 1998, p. 36-39)

The neighbour: HFML

- ✓ connection to FLARE and FELIX beamlines
- ✓ require large tuning range
- ✓ require (partly) high-resolution spectroscopic mode of FLARE

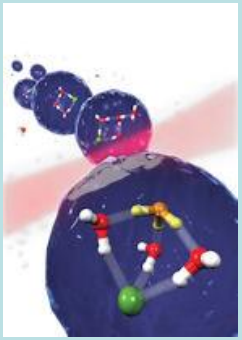


The FELIX User Facility

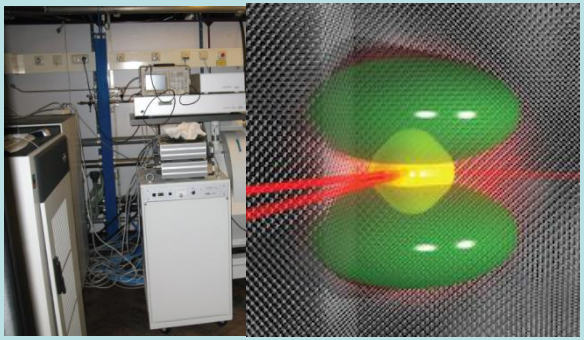
FELIX facility @ Nijmegen: User Laboratories

User laboratory 1 – FLARE & FELIX

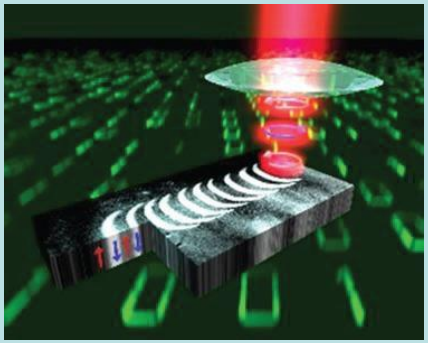
He-droplet machine
Havenith (Bochum) ✔



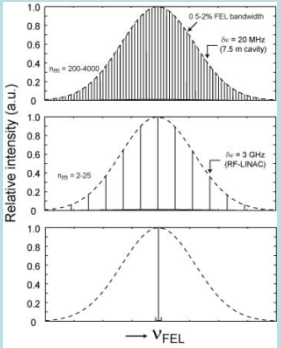
EPR spectrometer
EPSRC, Aeppli, Murdin ✔



Ultrafast laser system
Kimel & Rasing (RU) ✔

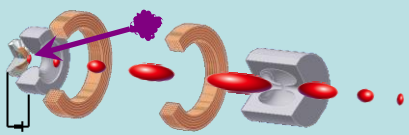


FLARE Diagnostic Station ✔

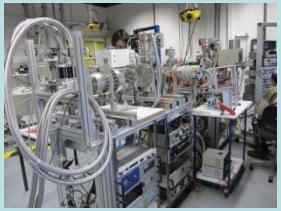


multi-purpose station with optical table

earmarked for electron diffraction setup (FLARE collaboration with Prof. J. Luiten, TUE)

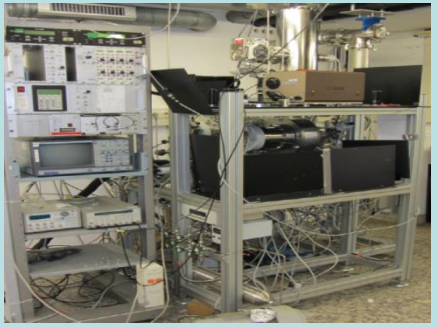


Cold 22-pole ion trap
Schlemmer (Cologne) ✔



Molecular beam apparatus ✔

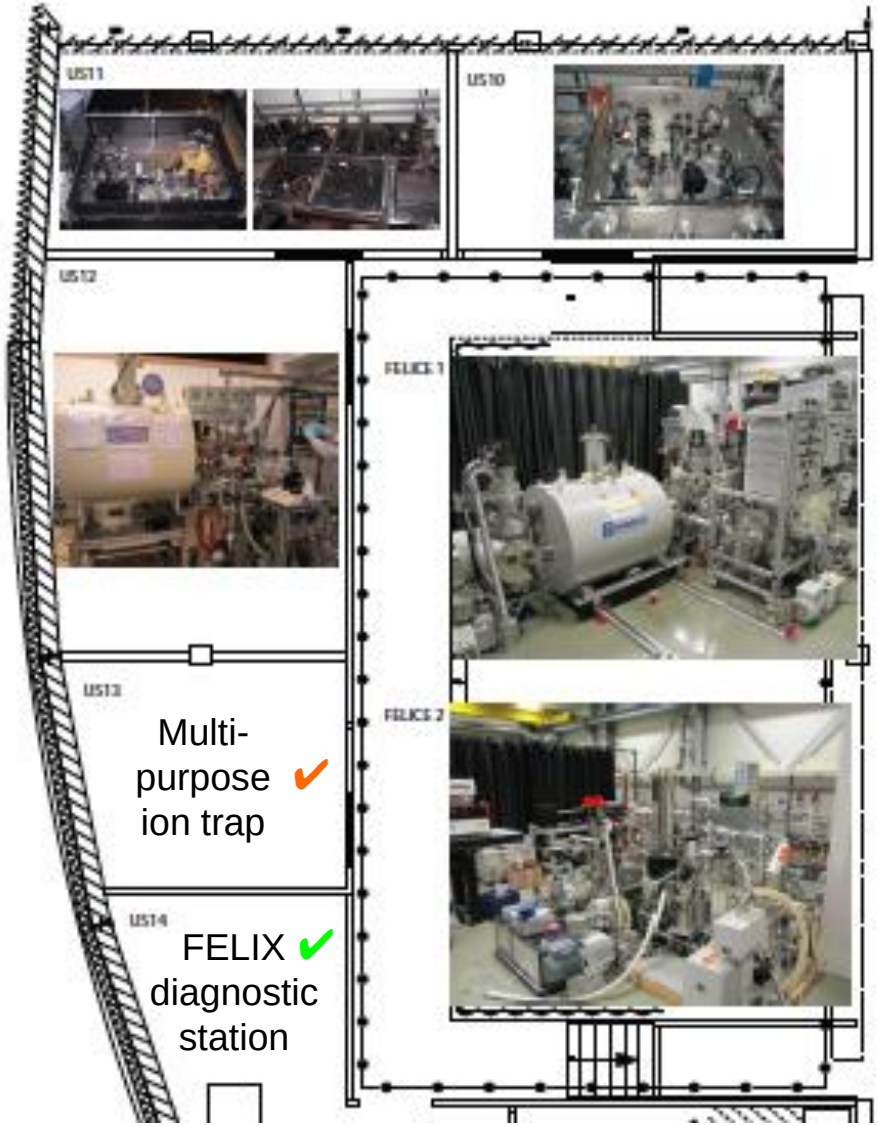
Metal cluster setup + ✔
Water cluster machine ✔



FELIX facility @ Nijmegen: User Laboratories

Ultrafast laser systems ✔

Versatile FTICR mass spectrometer ✔



Non-linear optics laboratory ✔

FELICE FTICR mass spectrometer ✔

FELICE cluster apparatus ✔

User laboratory 2 - FELIX & FELICE

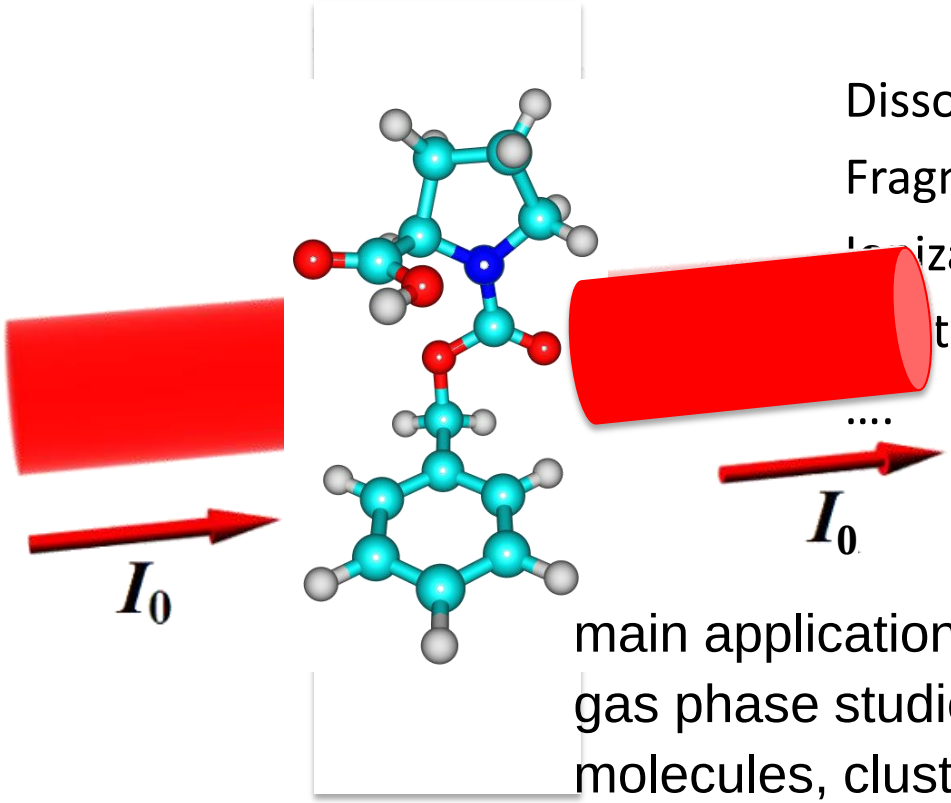
a) high peak brightne
nonlinear nts exploiting the time resolution

not today

TR ser Experiments

b) high peak intensity:
action spectroscopy exploiting the fluence and tunability

Introduction Action Spectroscopy



Dissociation

Fragmentation

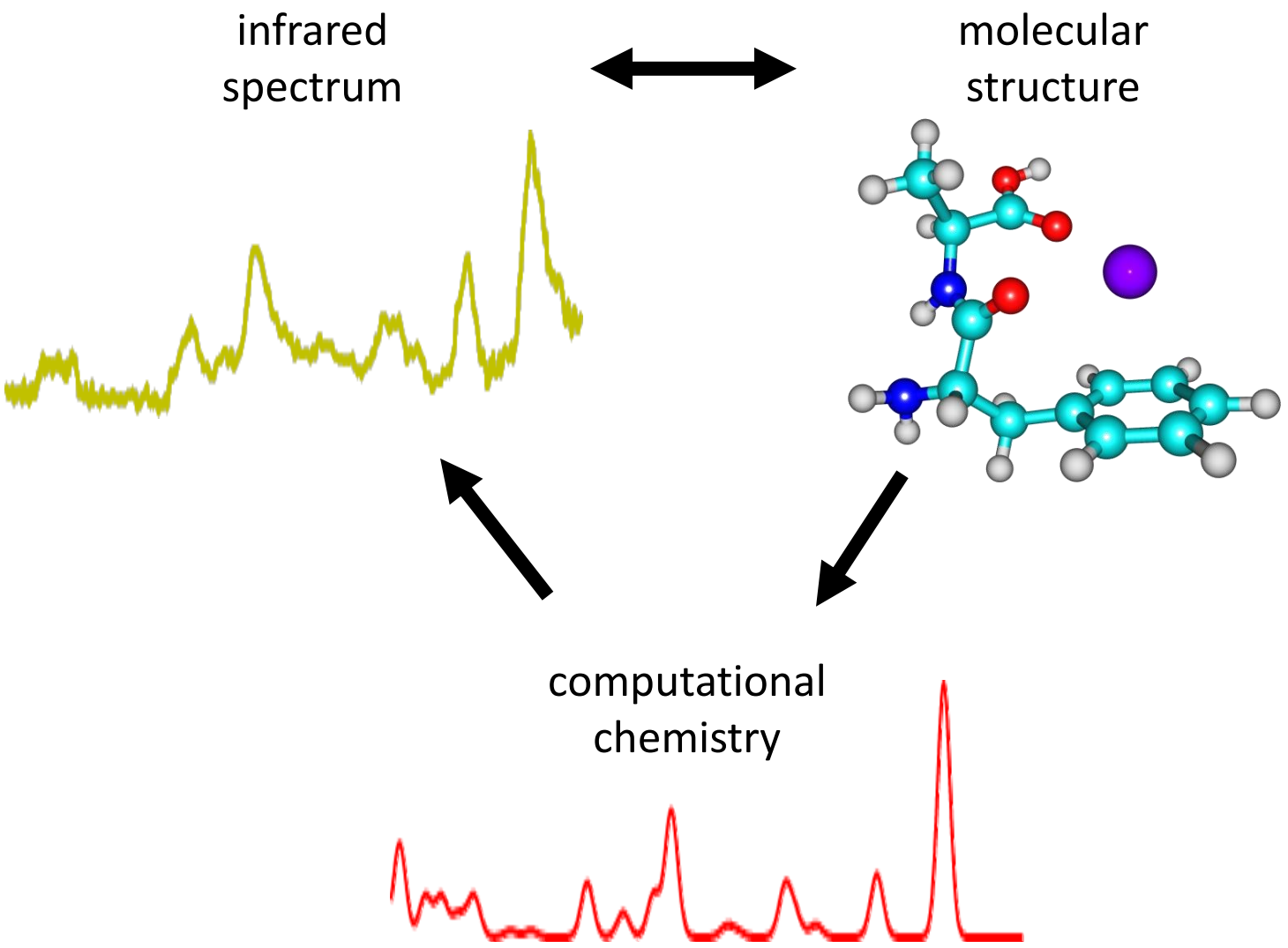
Ionization

Electron Loss

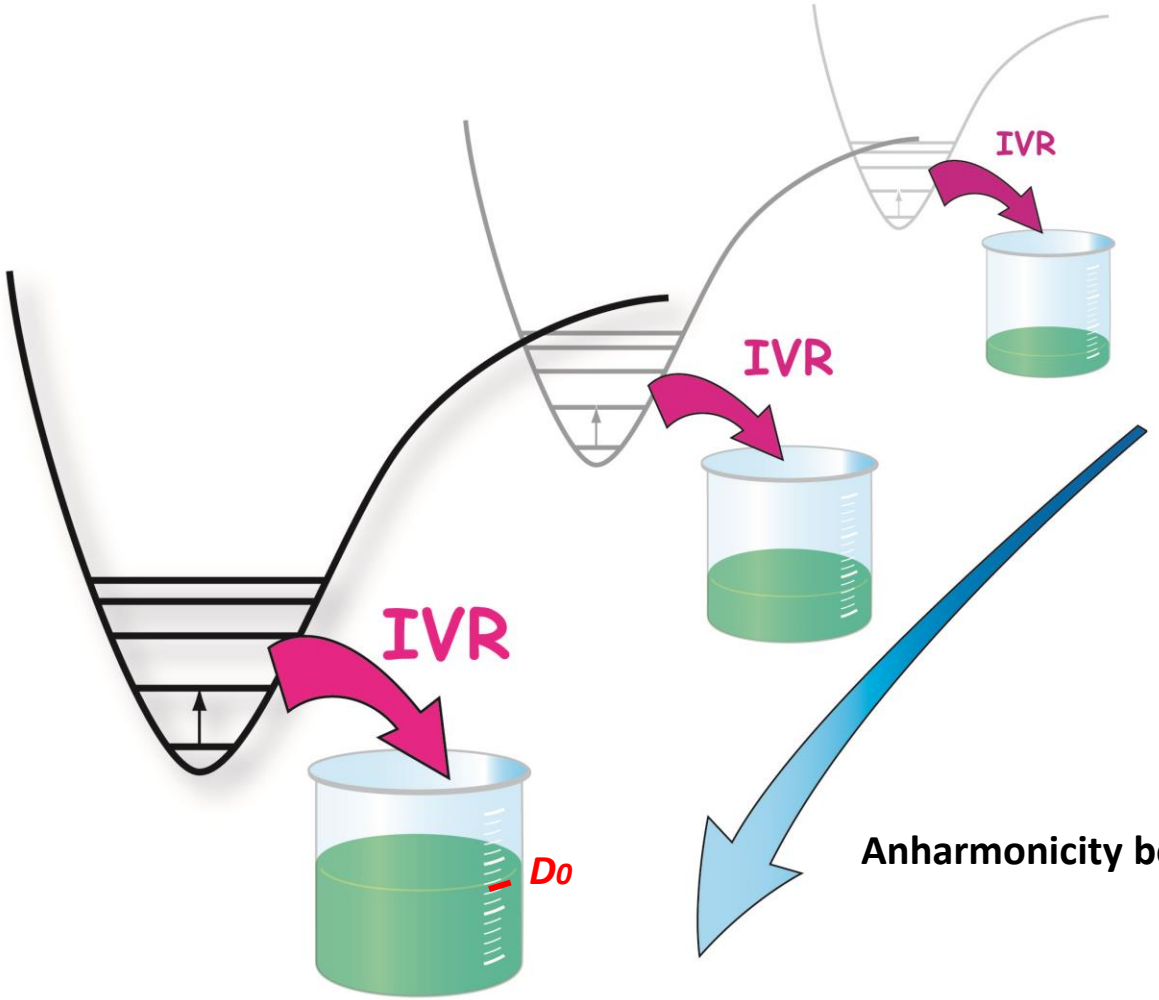
....

main application:
gas phase studies
molecules, clusters, complexes
neutral, ionic species
molecular beams, ion traps

Infrared spectroscopy – molecular structure



Intramolecular vibrational redistribution mediated multiple photon excitation



A few examples

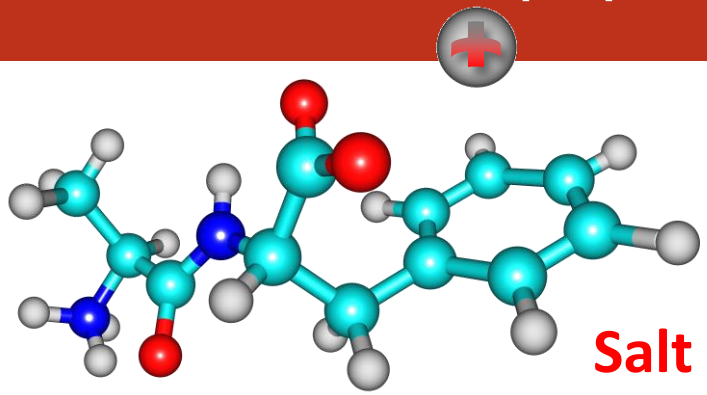
-

emphasis on THz spectral range

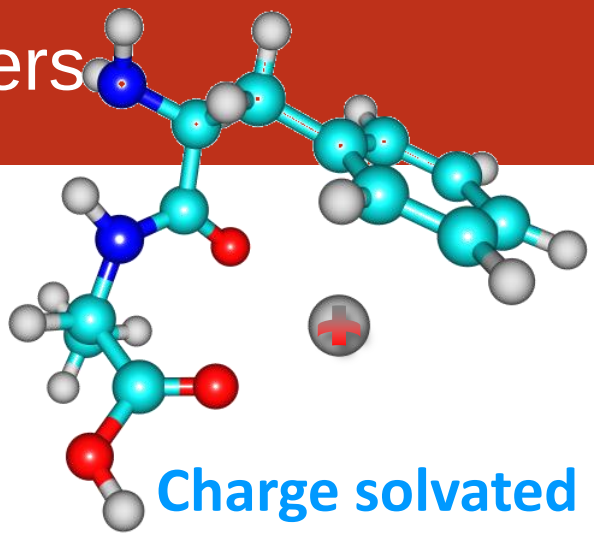
Example

Binding motif of metal ions to amino acids and small peptides

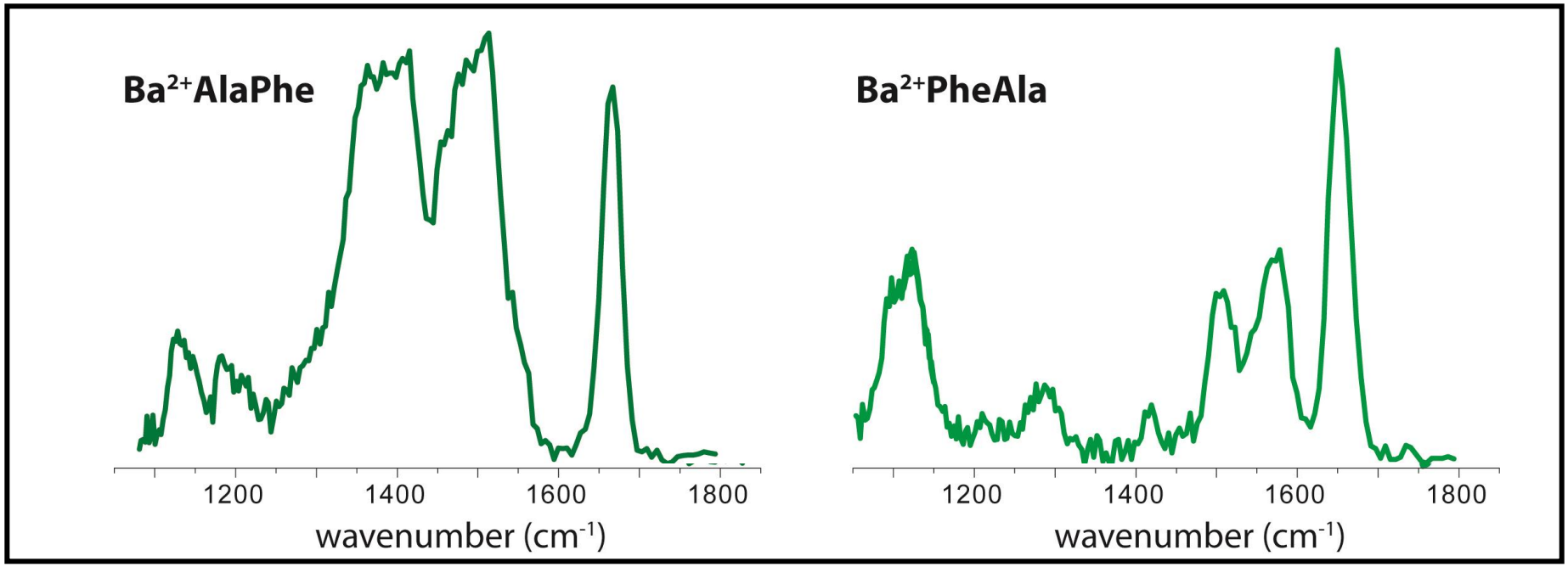
CS versus SB: peptide sequence matters



Salt bridge

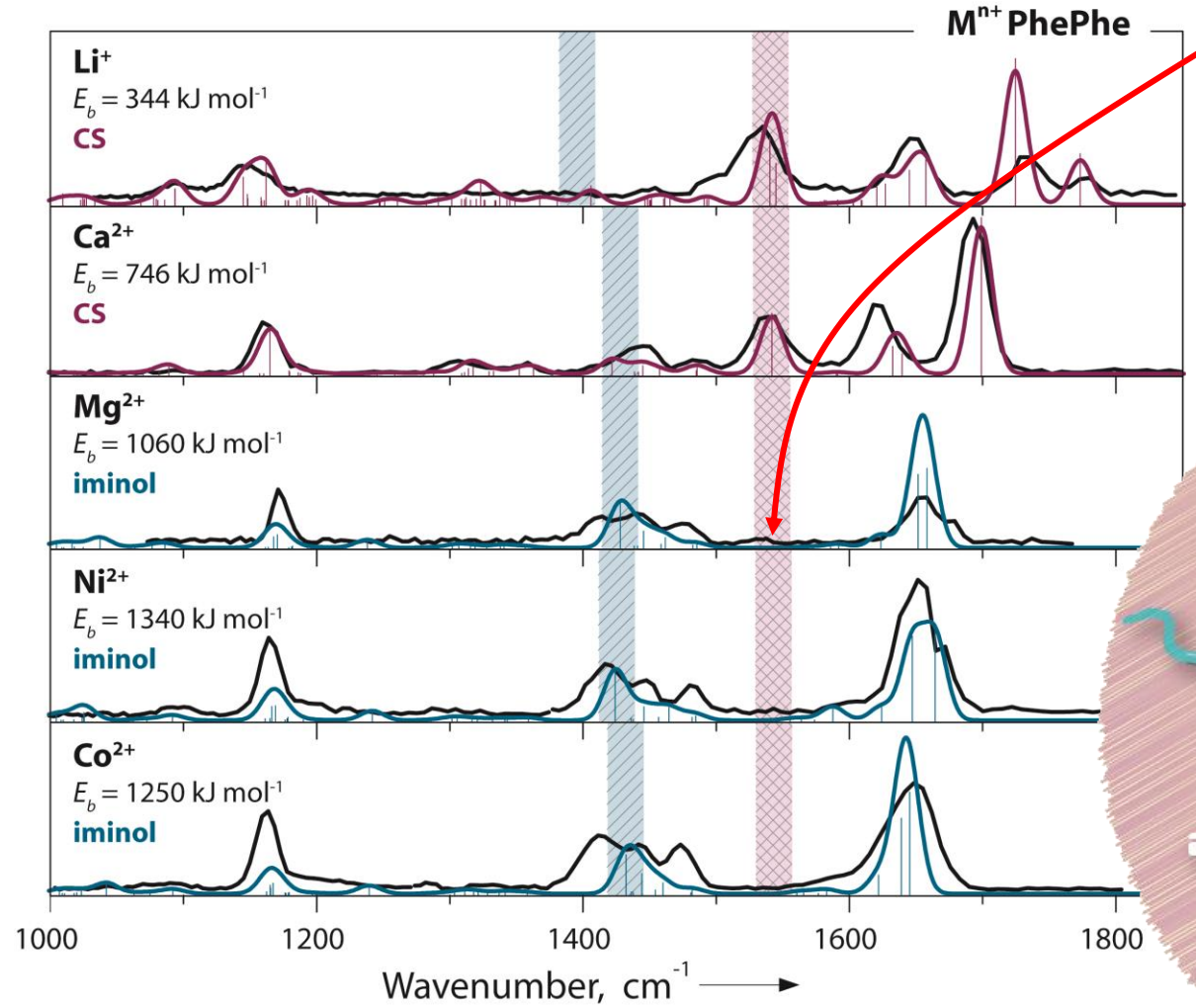


Charge solvated



Dunbar et al., J. Am. Chem. Soc. 2009

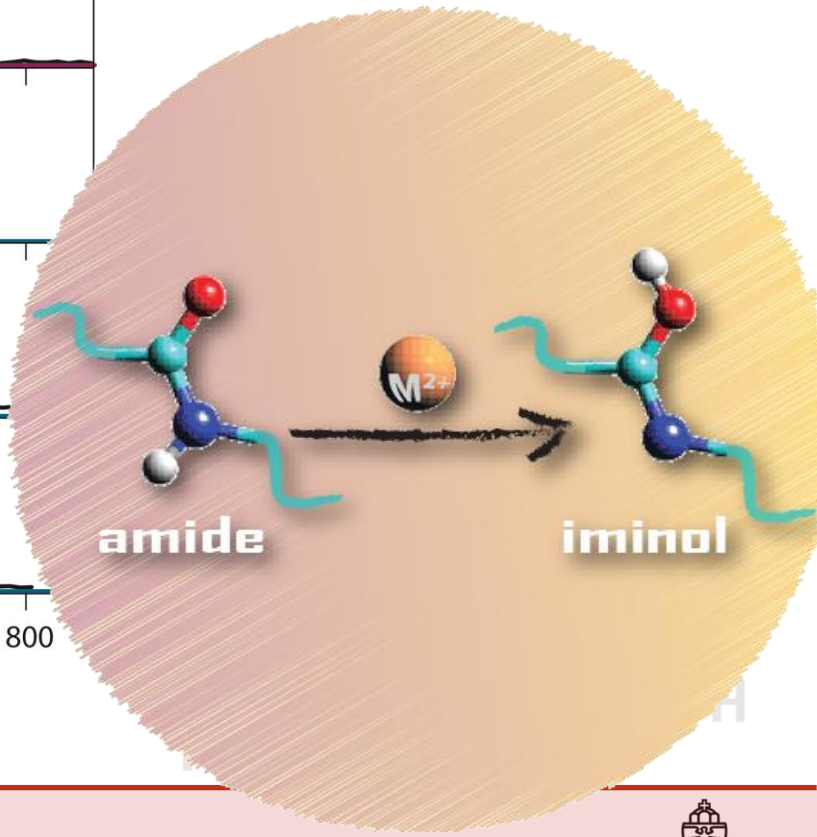
A new motif: iminol



No Amide II band

Strongly binding metals

Keto-enol tautomerization

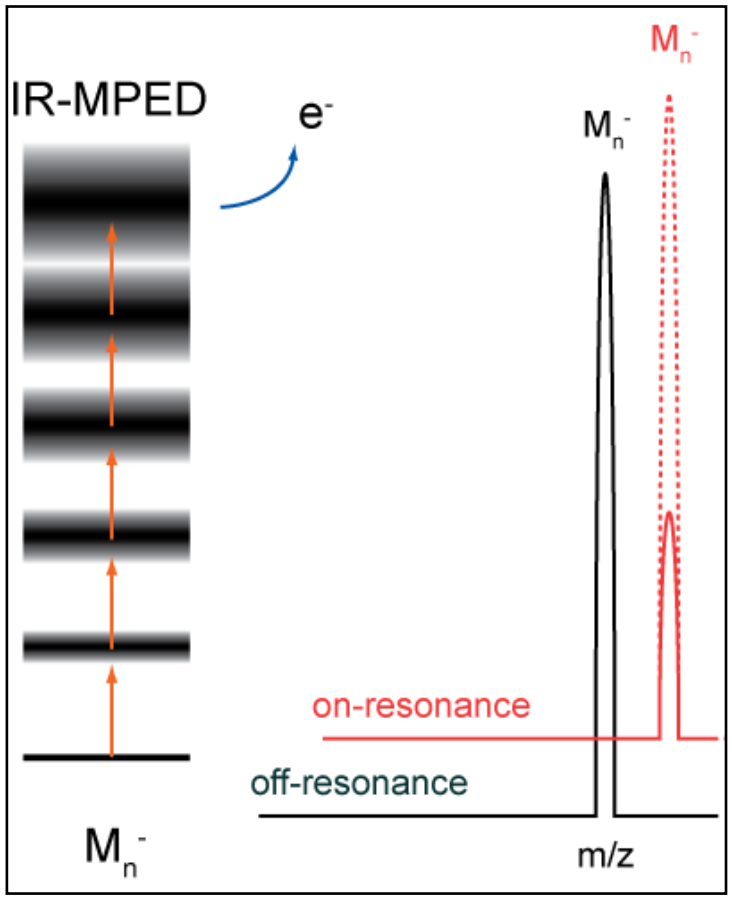


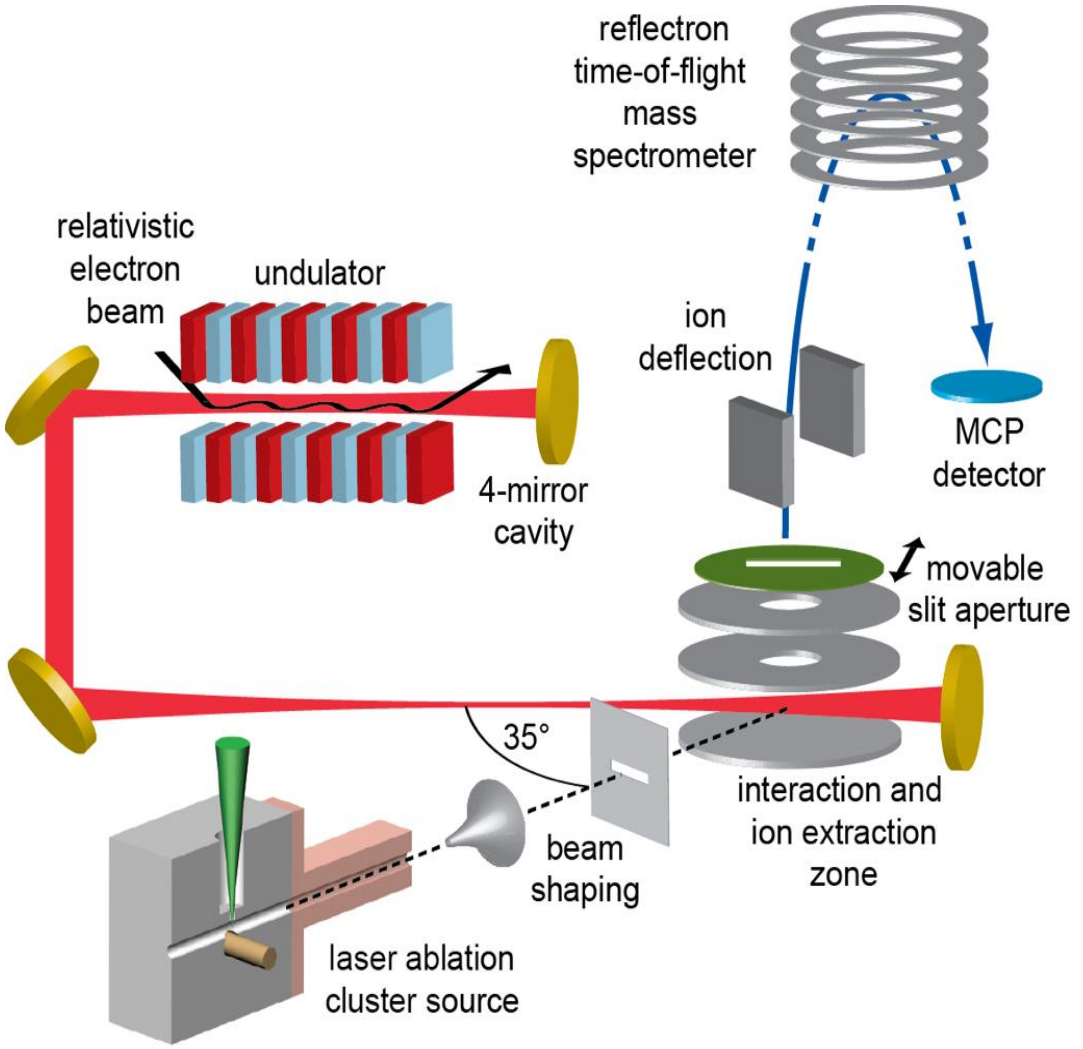
Dunbar, Steill, Polfer, Berden, Oomens, *Angew Chem Int Ed* **2012**

Example

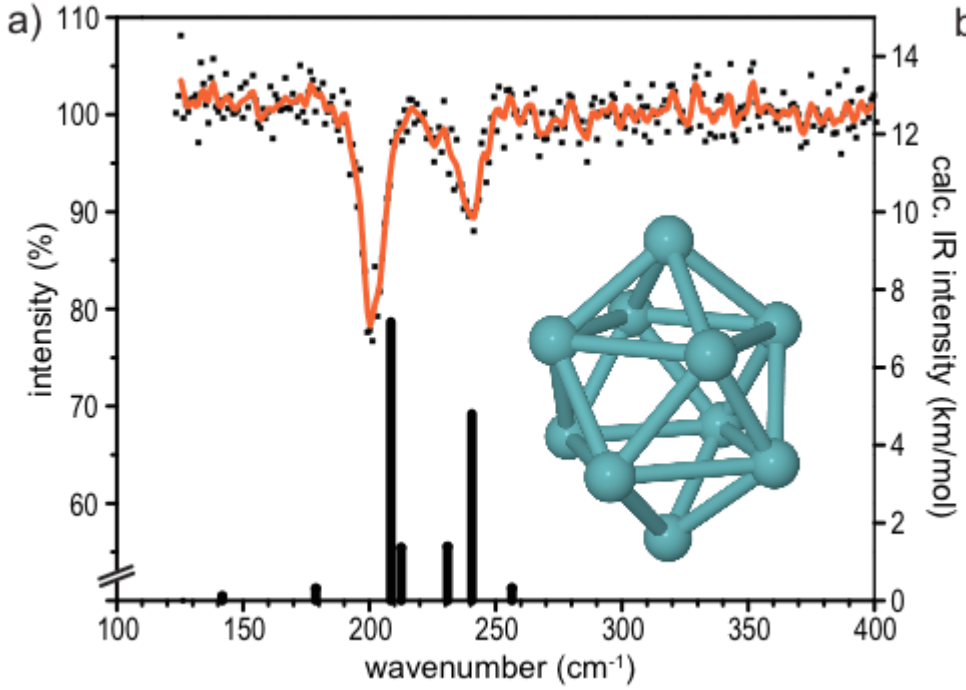
New method for structure determination of cluster anions using FELICE

FELICE: a new technique for anion spectroscopy

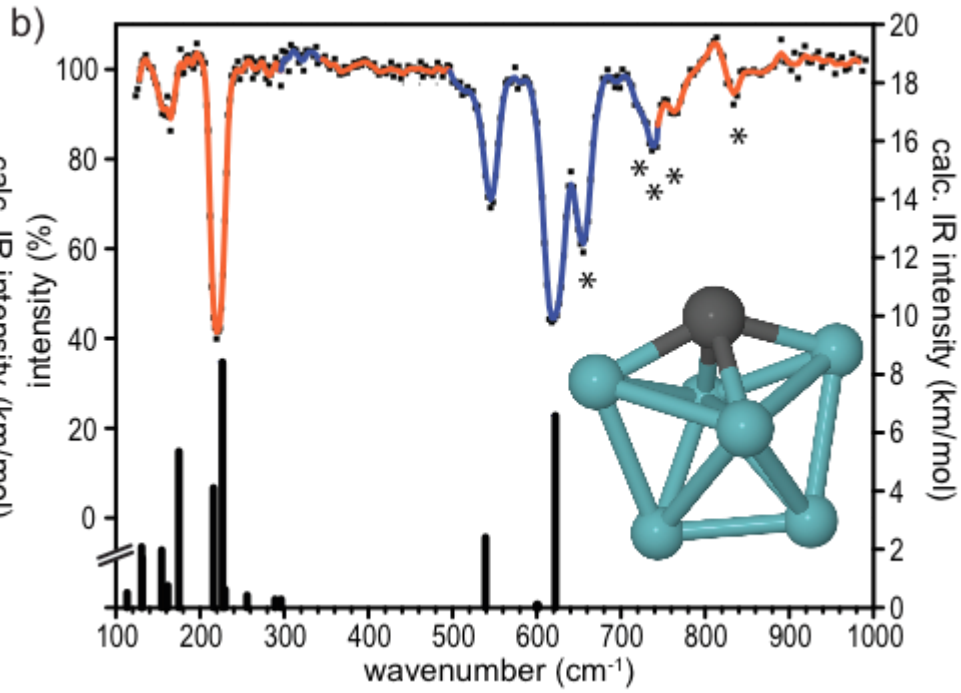




Structure of anionic Niobium clusters



Nb^-_{10}



Nb_6C^-

Haertelt *et al*. J. Phys. Chem. Lett. 2011, **2**, 1720

Timeline FELIX @ Nijmegen

Future

Very happy and long life together
with many "old" and new visitors
coming and returning to
FELIX @ Nijmegen!

Thank you!