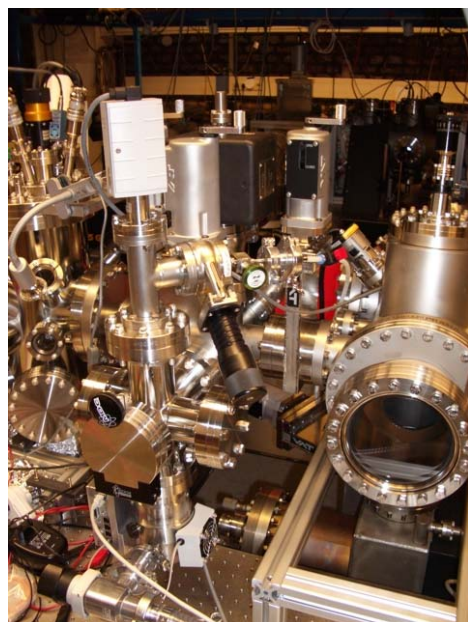
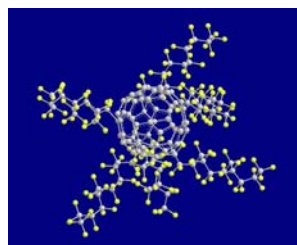
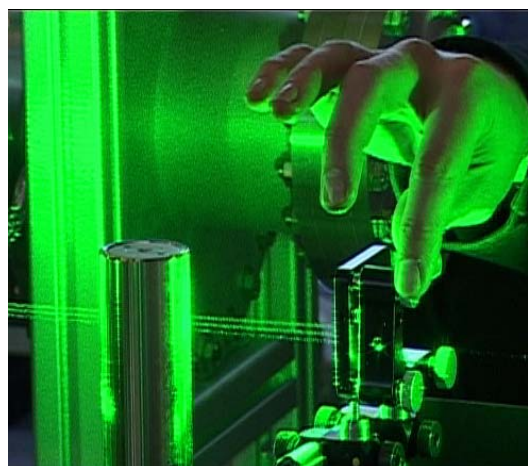


Olomouc 2005

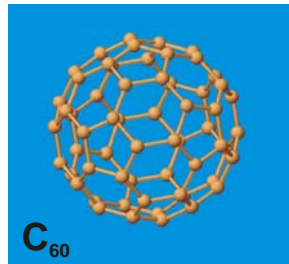


Status and Challenges
In Molecule Interferometry

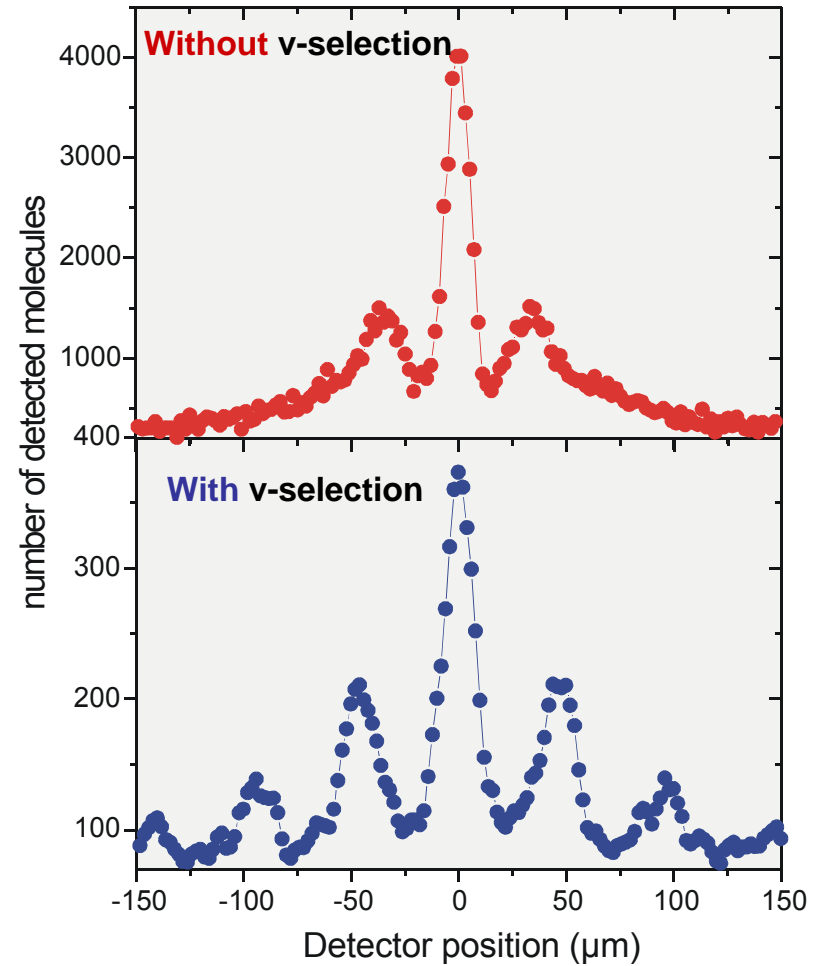
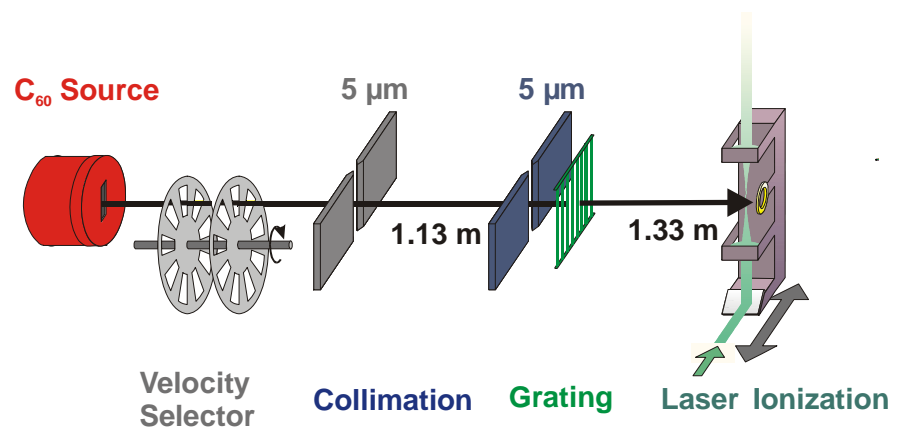
Markus Arndt
Institut für Experimentalphysik
Universität Wien



Short reminder:
Far-field diffraction at a nanograting

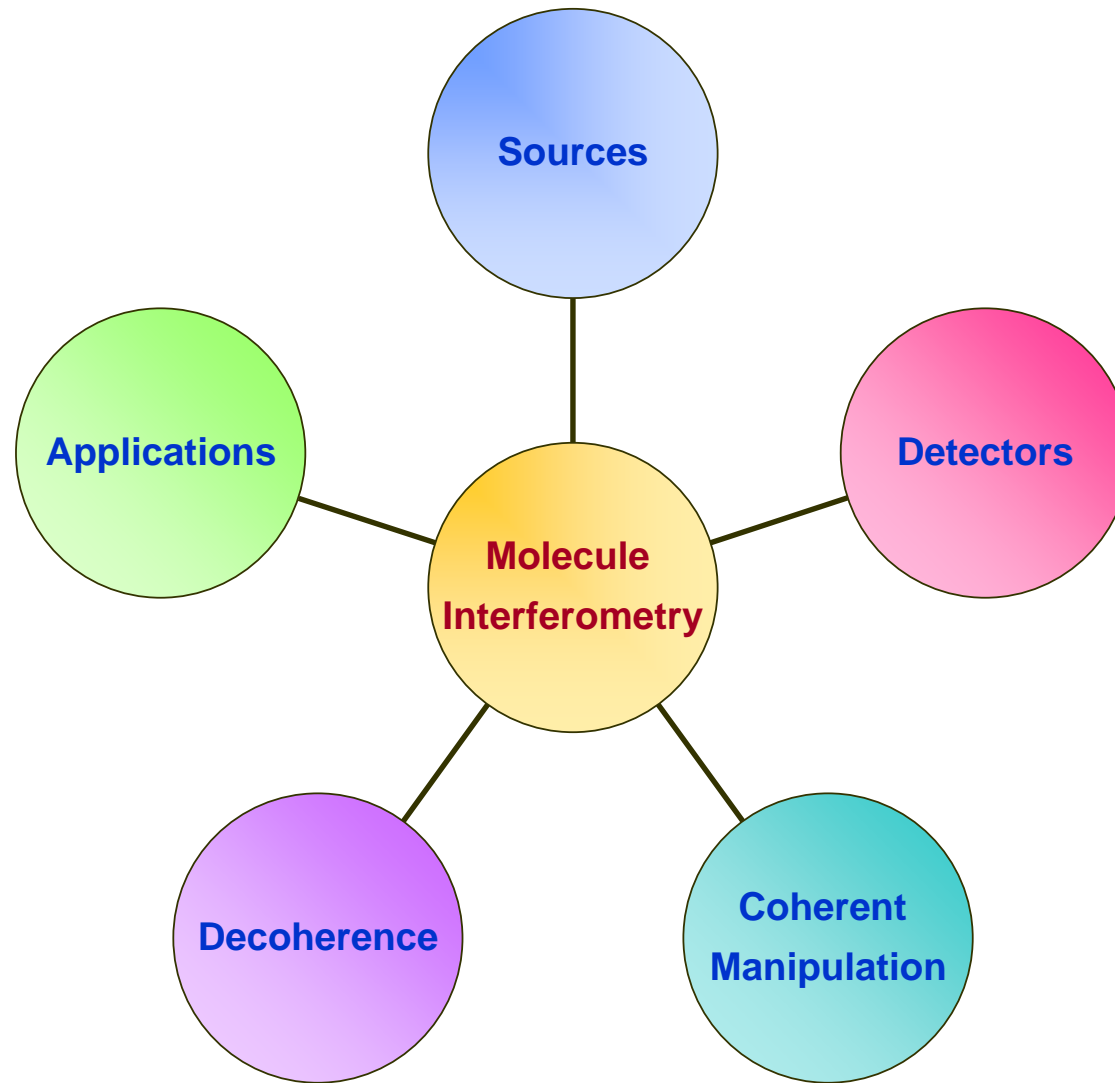


Interference demonstrated !



M. Arndt et al., *Nature* 401, 680 (1999).

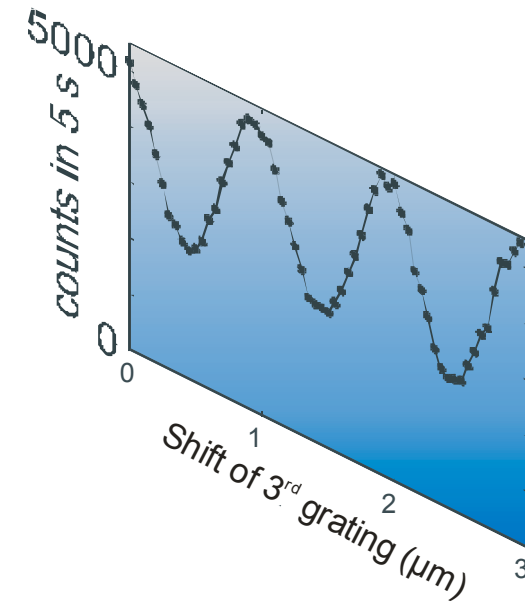
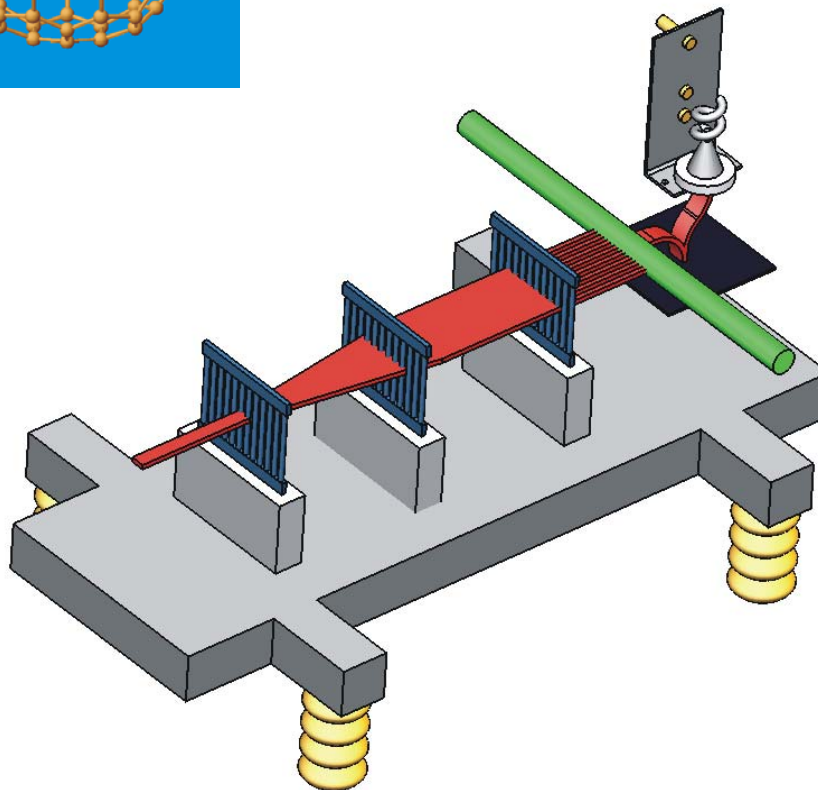
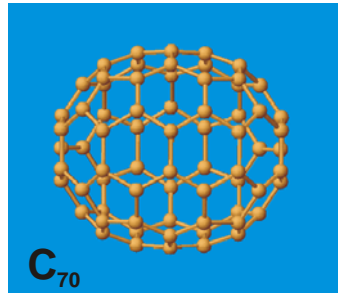
O. Nairz, M. Arndt, A. Zeilinger, *AJP* 71, 319 (2003).



STATUS:

Interferometry with
large molecules

Talbot-Lau Near-Field interferometry



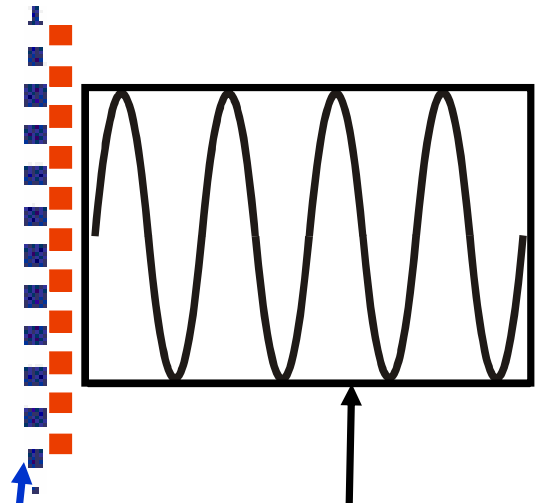
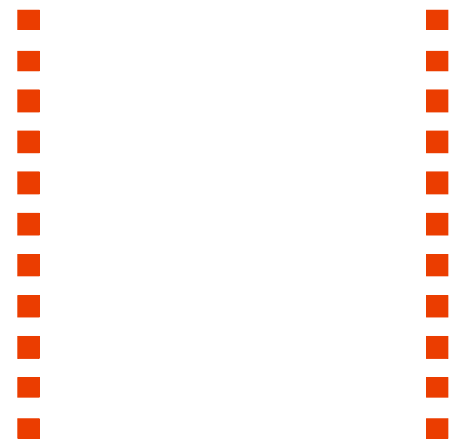
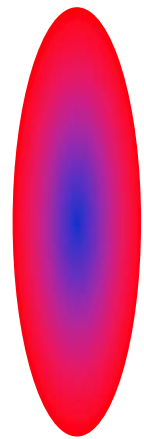
Visibility:

$$V = \frac{I_{\max} - I_{\min}}{I_{\max} + I_{\min}}$$

Pattern Formation in a Talbot-Lau Interferometer

- 1. Grating: Coherence Prepar.
- 2. Grating: Diffraction
- 3. Grating: Scanning Mask

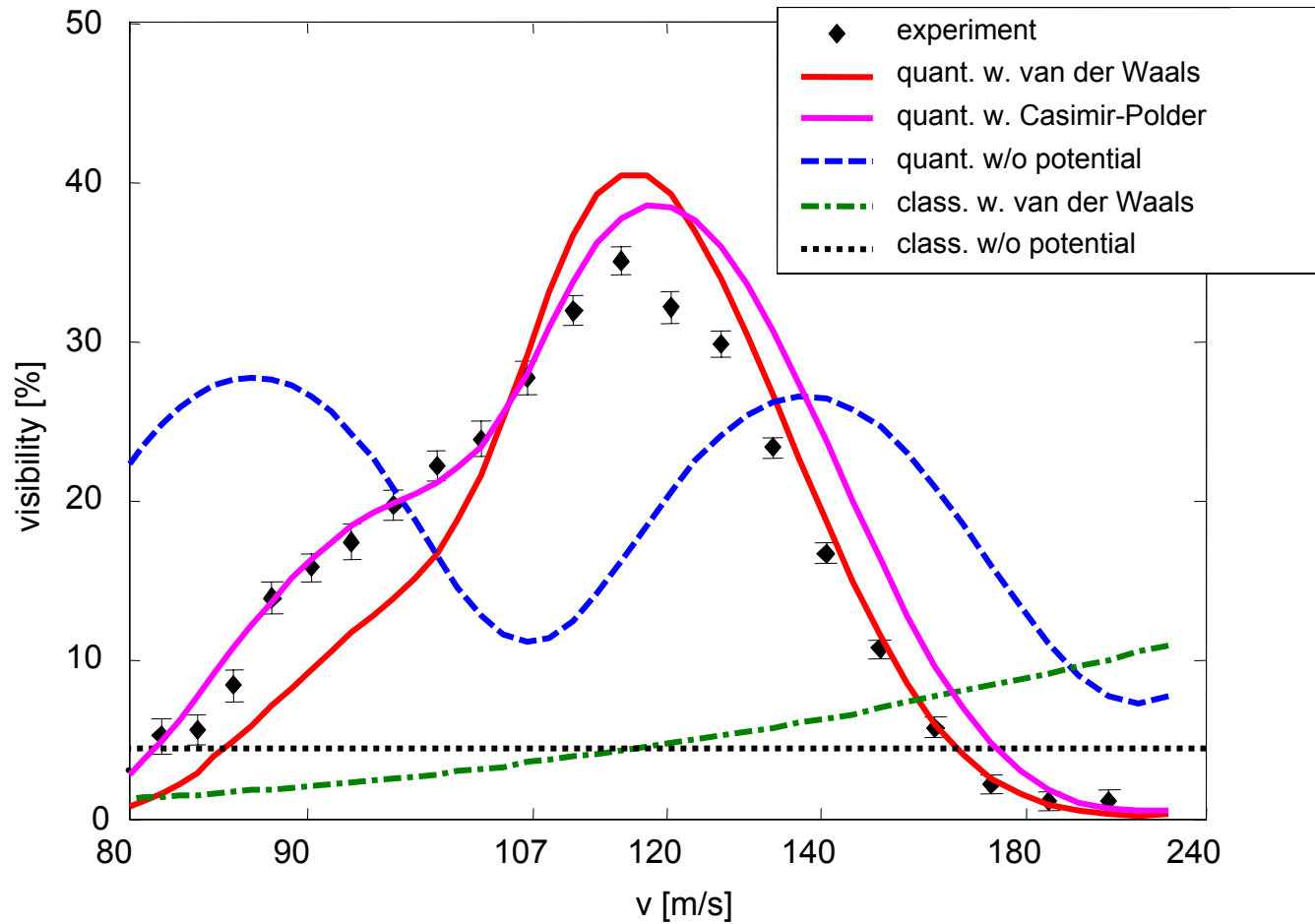
Incoherent Molecular beam



Number of Molecules behind 3rd Grating

Interference generates a molecular pattern. Its period equals the period of the gratings.

Prove of the wave nature:
Variation of interference contrast with v (λ)



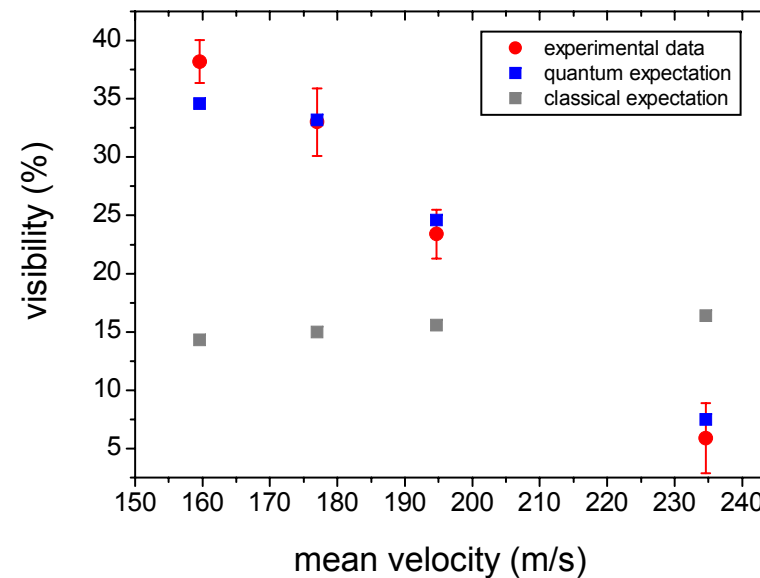
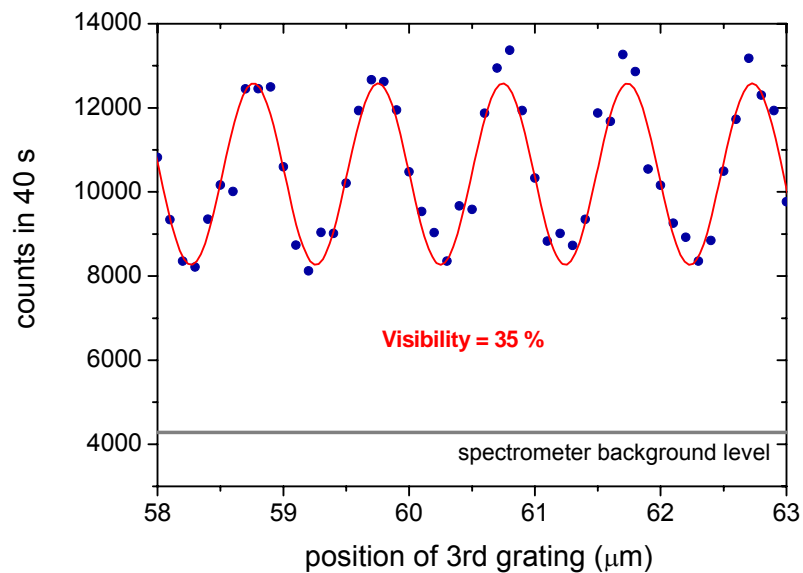
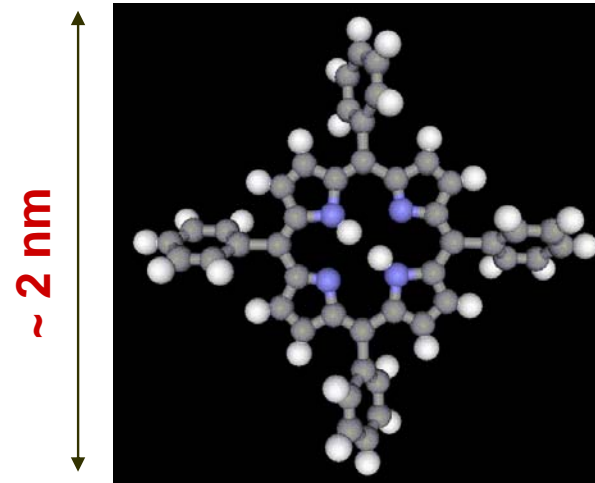
Interferometry with Porphyrins: $C_{44}H_{30}N_4$ (TPP)

Question:

Influence of symmetry on interference contrast?

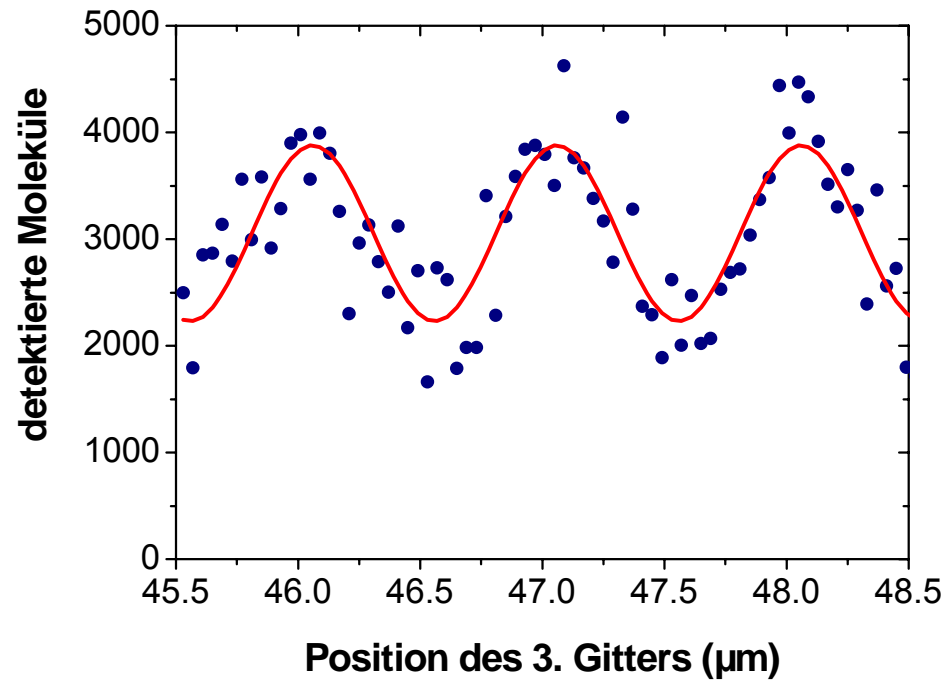
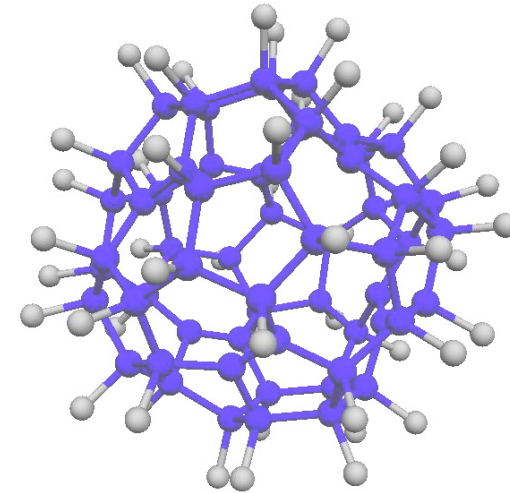
Answer:

Nearly perfect wave behavior!



Current world record in mass & complexity

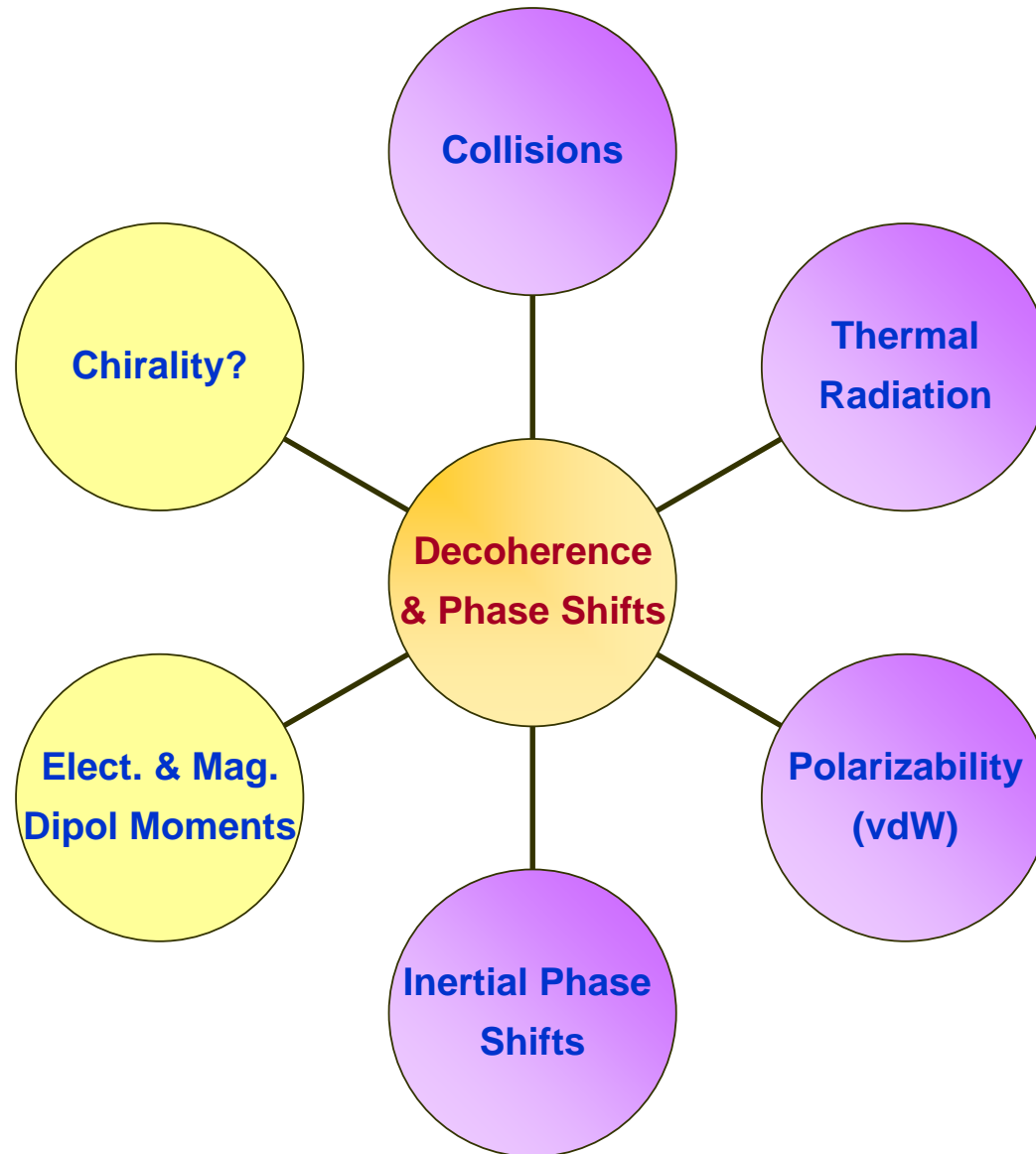
- + $C_{60}F_{48}$
- + 1632 amu !
- + 108 Atoms in a *single object* !
- + Isomers with different symmetries



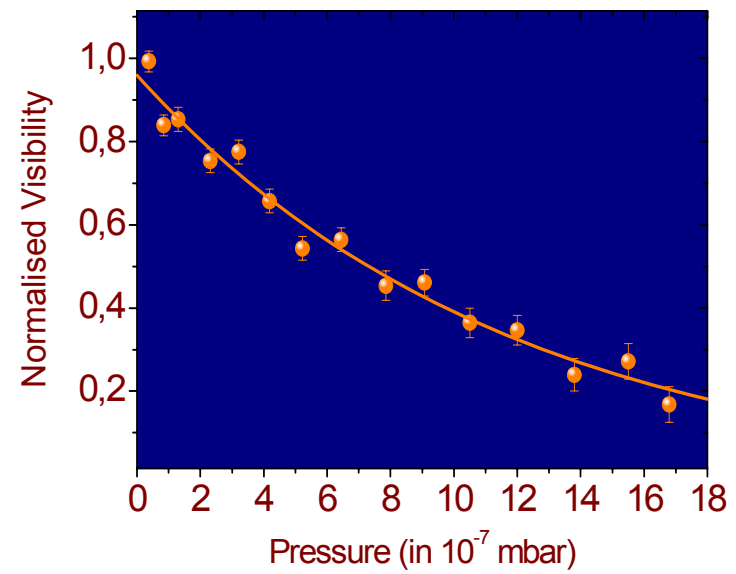
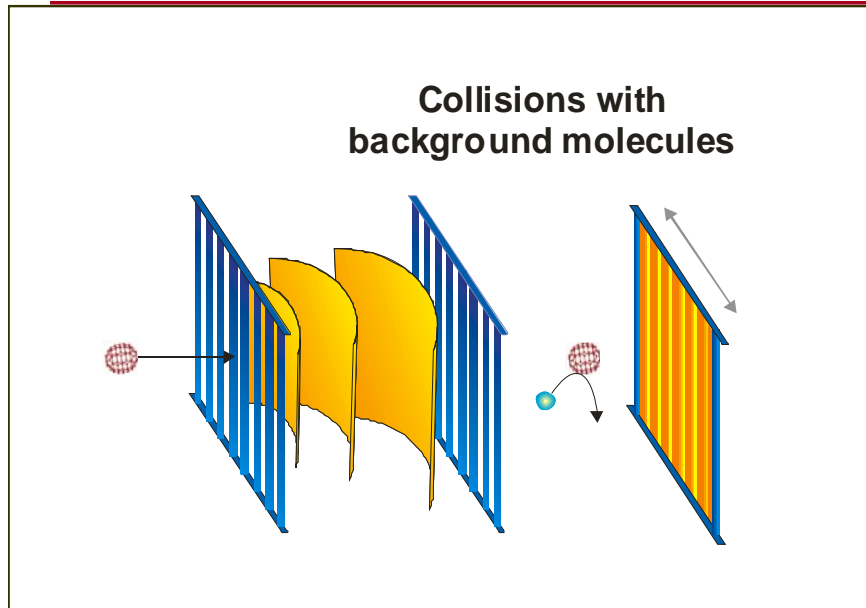
Also here:
Quantum interference !

Phys. Rev. Lett 91, 90408 (2003).

Decoherence & Phase Shifts studied ...



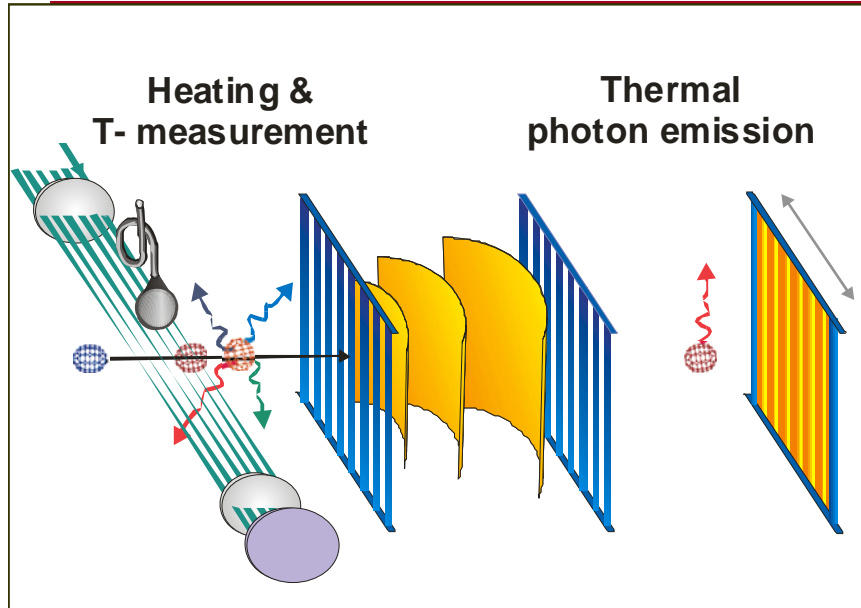
Decoherence: Collisions



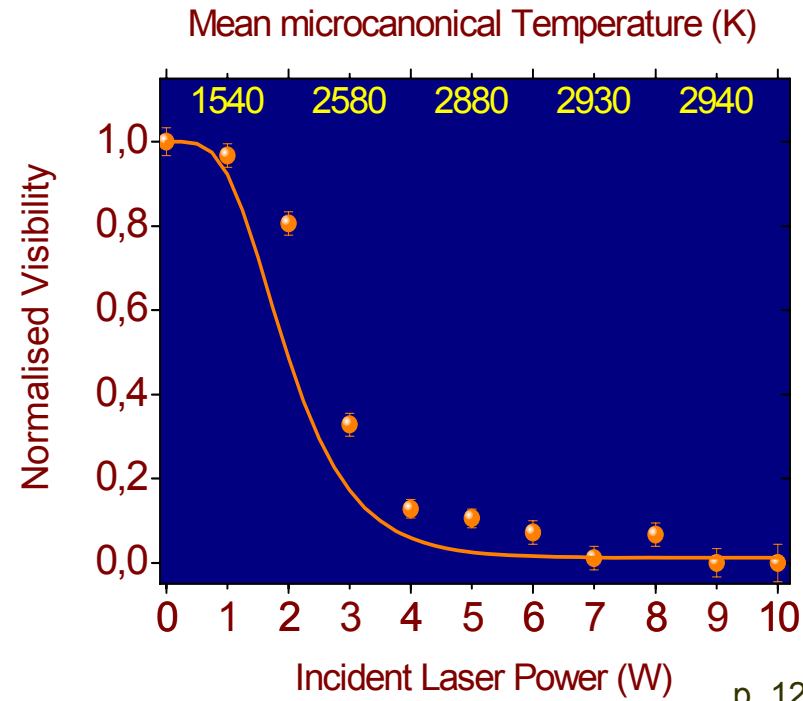
Phys. Rev. Lett. 90, 160401 (2003).

Physics Today (2005).

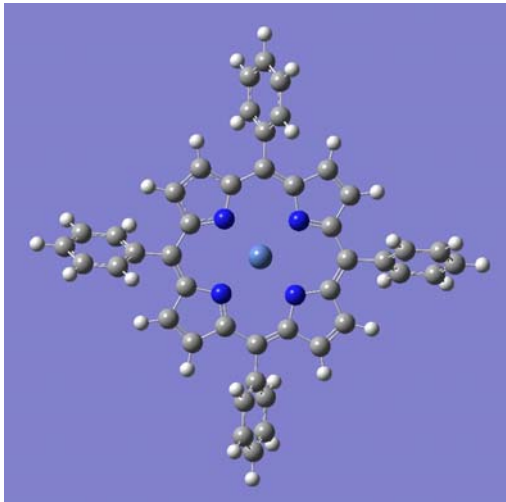
Decoherence: Thermally induced radiation



NATURE 427, 711–714 (2004).



***Novel Molecules:
Similar mass but different physical properties...***



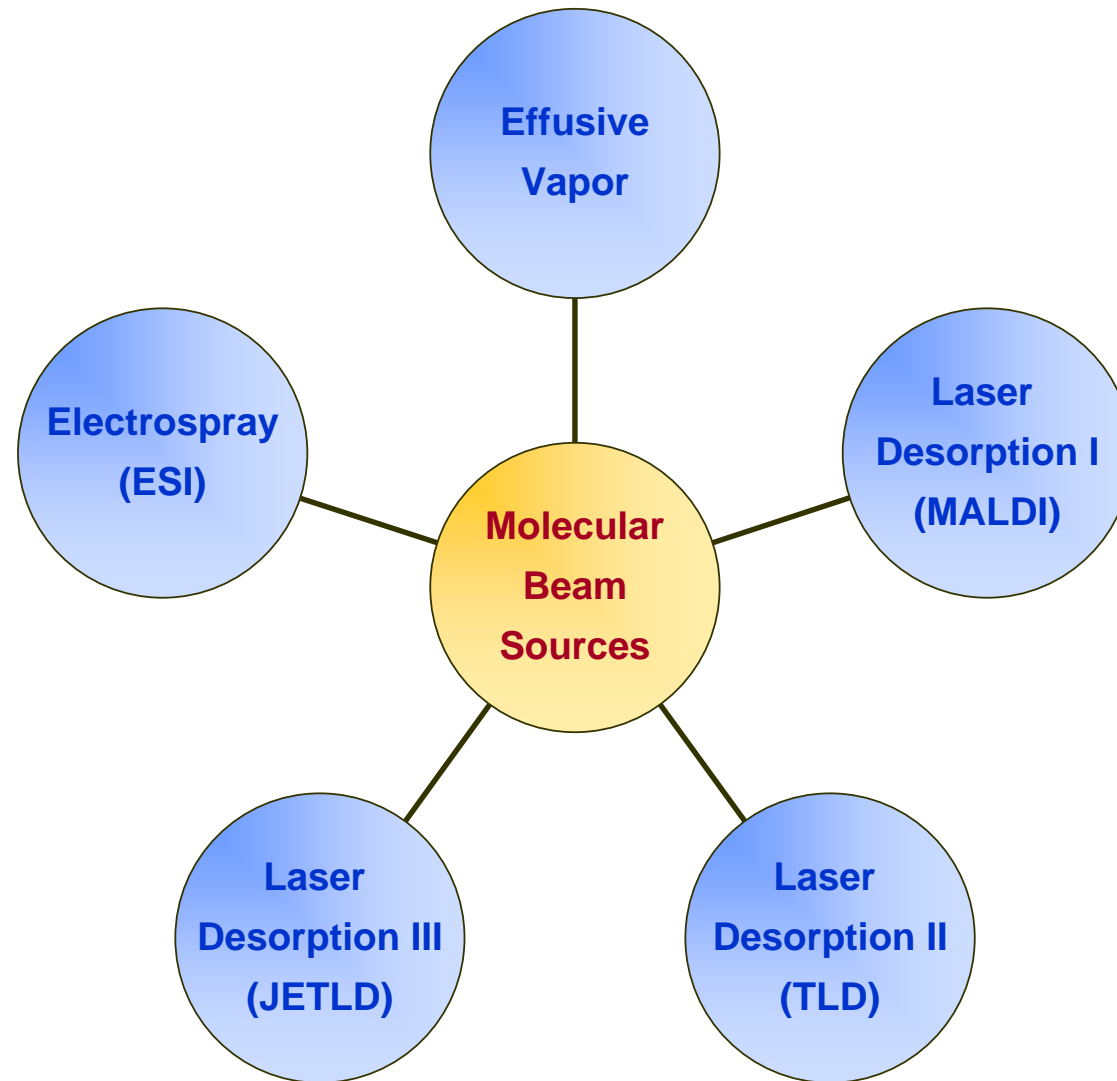
- ***TPP with electric dipole moment (COOH, ...)***
- ***TPP with magnetic moment (Rare earths, ...)***

Question:

- ***Molecule/Grating interaction: Dephasing ?***
- ***Predictions for proteins ?***

Perspectives:

Developments for
the near future

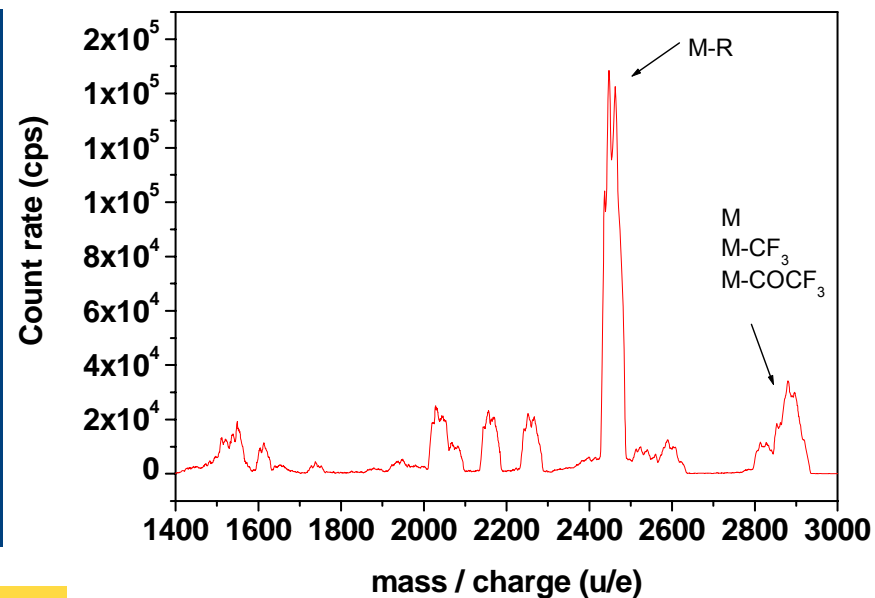
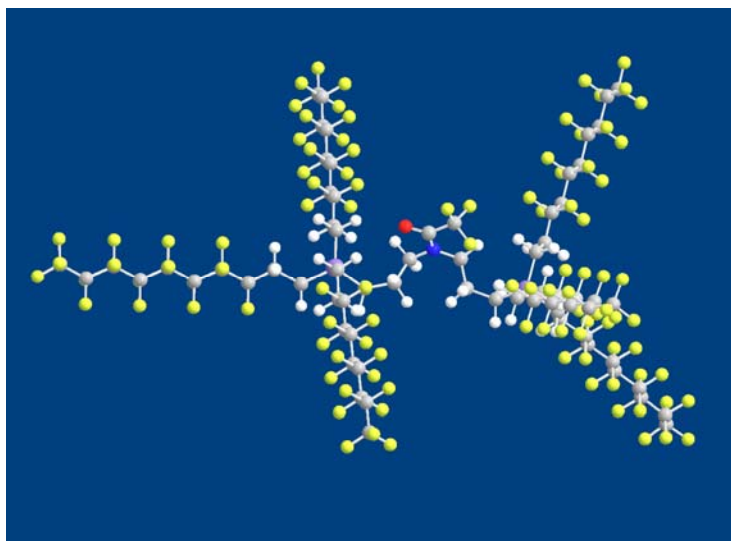


STATUS:

Effusive Sources up to 7000 u

Thermal Source
Perfluorinated Hydro-carbons

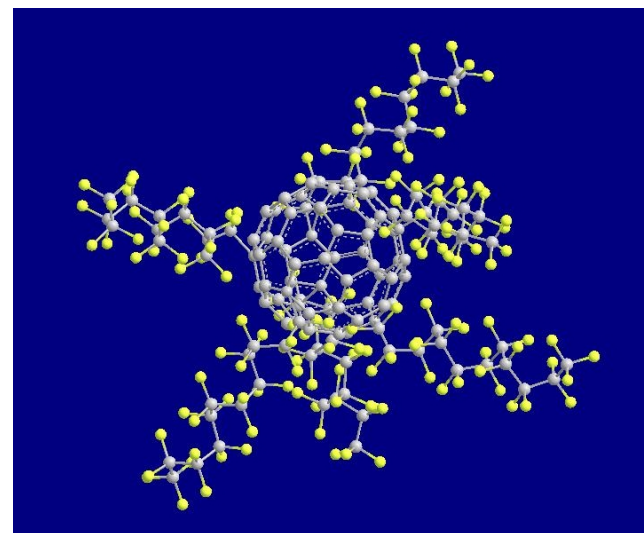
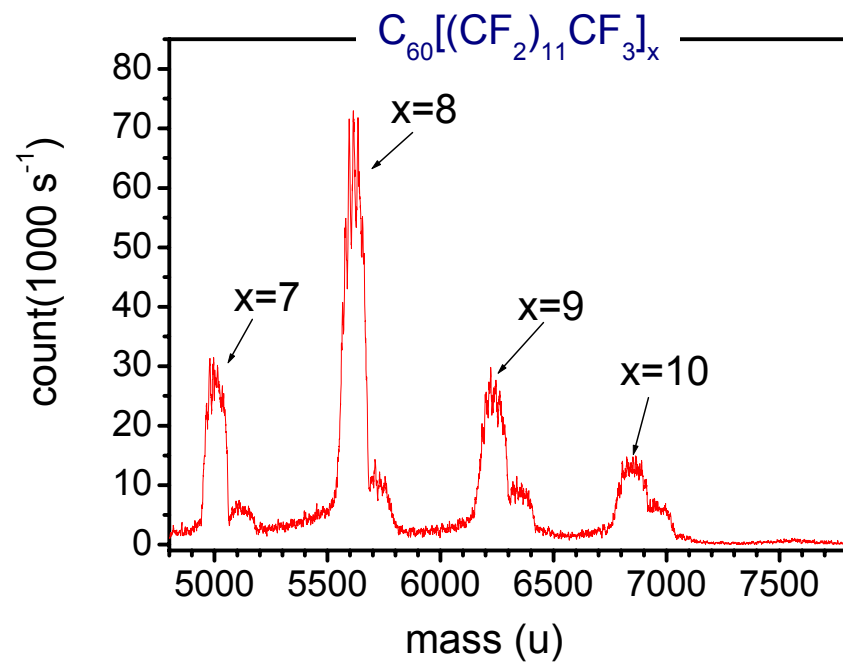
N,N-Bis[3-[tris(2-perfluorooctylethyl)silyl]propyl]-trifluoroacetamide



- $M = 2934 \text{ amu}, C_{68}H_{36}NOSi_2F_{105}$
- **Atoms/Molecule: 213**
- **Extension: 4 x 3x 2 nm³**
- **Dipole moment: ~ 9 Debye**
- **Polarizability: ~ 100 Å³**
- **Velocity: 80 m/s**

- **Count rate: OK for Interferometry !**
- **Detection: EI-Ionization QMS**

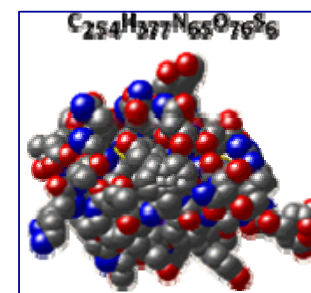
Can we go even further ?
Thermal Beams of Fullerene derivatives !



Only 6 side chains shown

Our current „source record“

m ~ 7000 u, v = 80 m/s



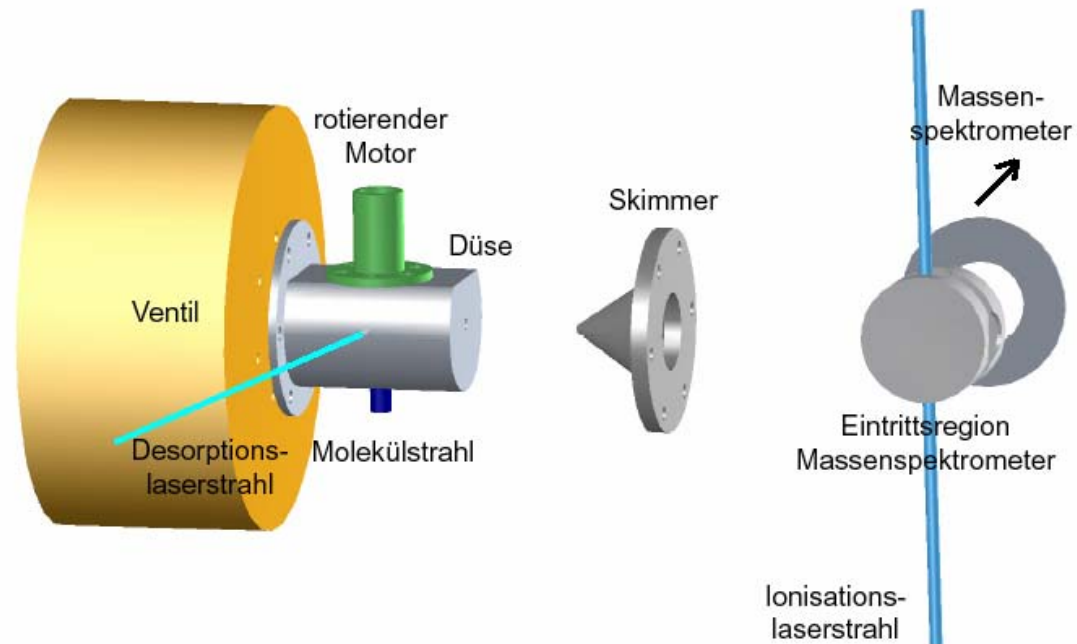
Insulin

STATUS:

Jet-expanded Laser Desorption

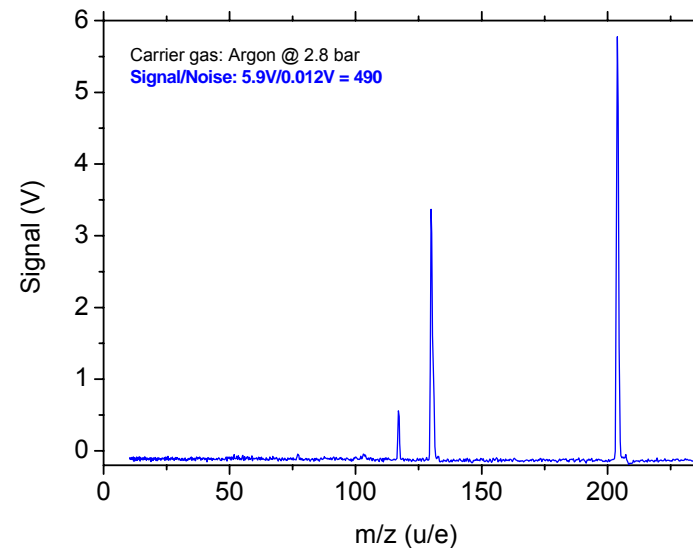
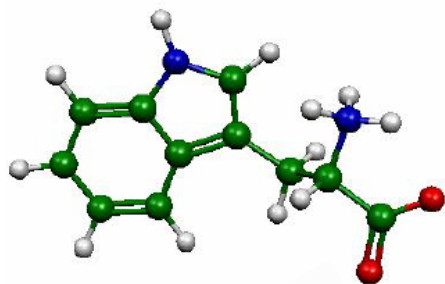
Jet-expanded laser desorption (JETLD)

- Neutral & directed beams of biomolecules
- Excellent velocity selection (1:1000)

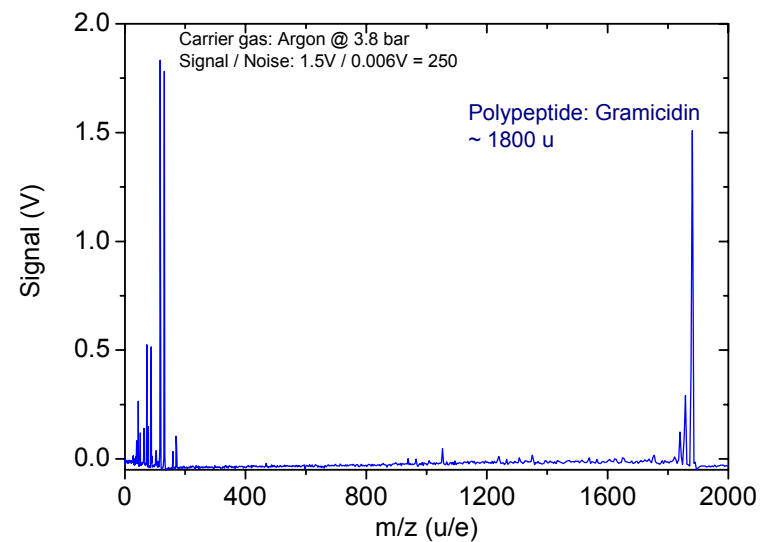
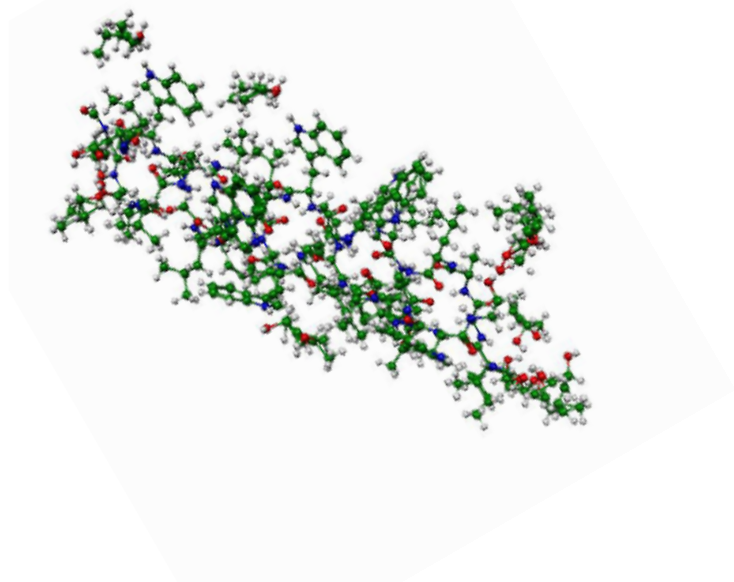


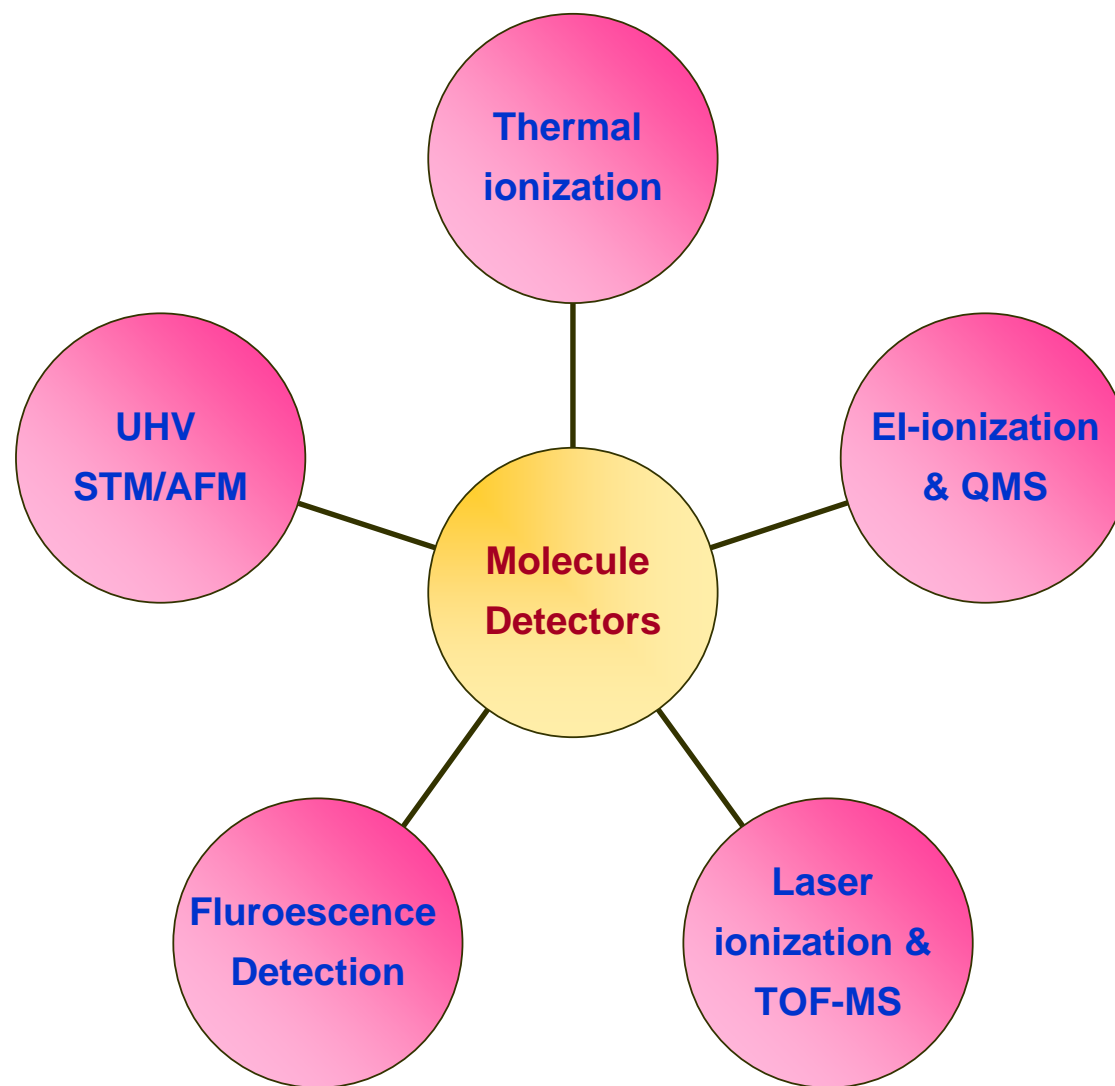
Laser desorption & Multiphoton ionisation
Intense neutral beams of biomolecules detected !

Amino acids: Tryptophan

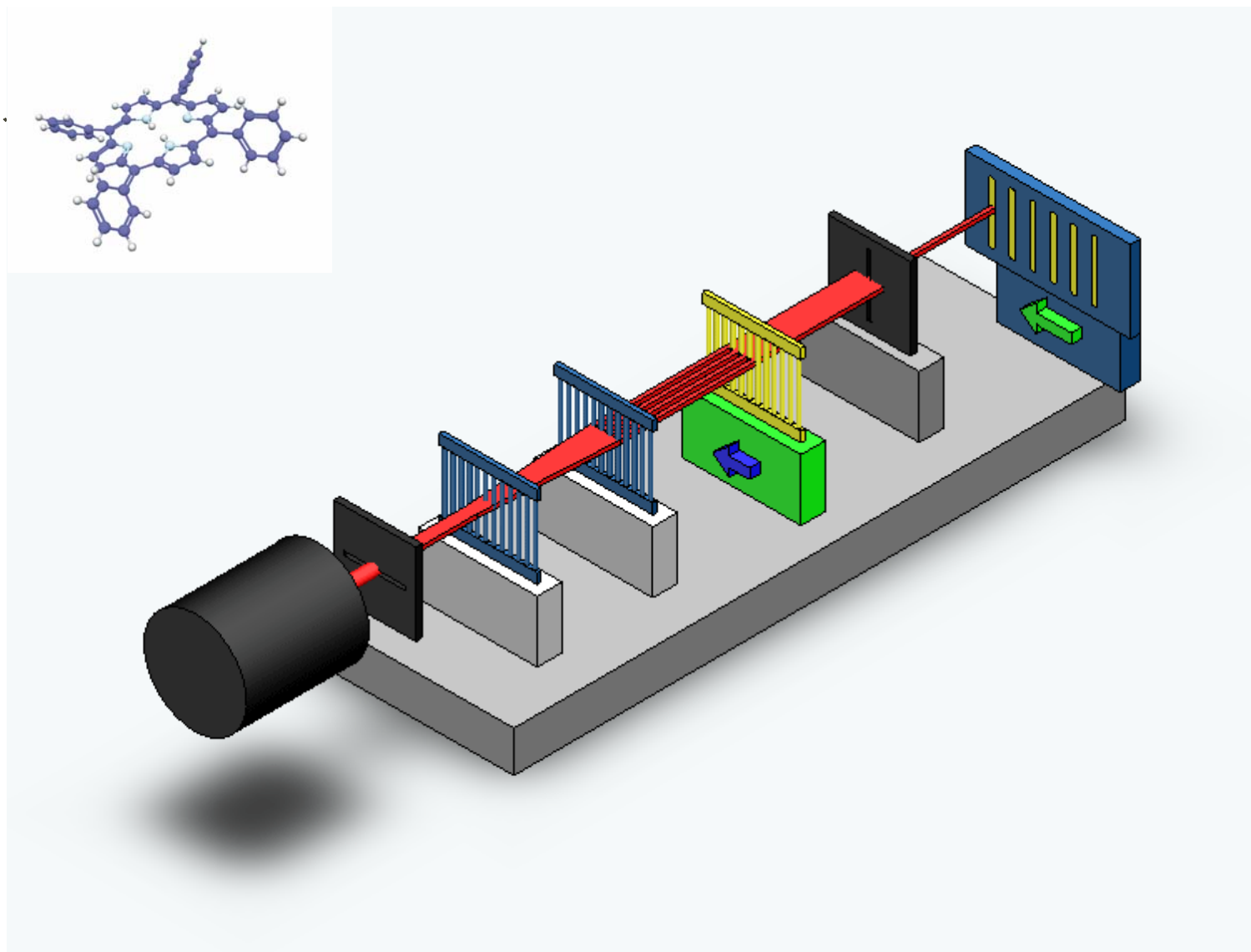


Polypeptide: Gramicidin

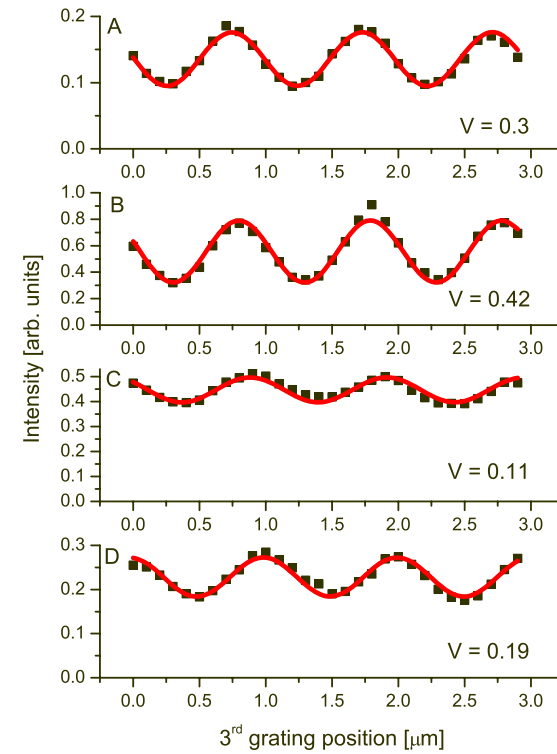
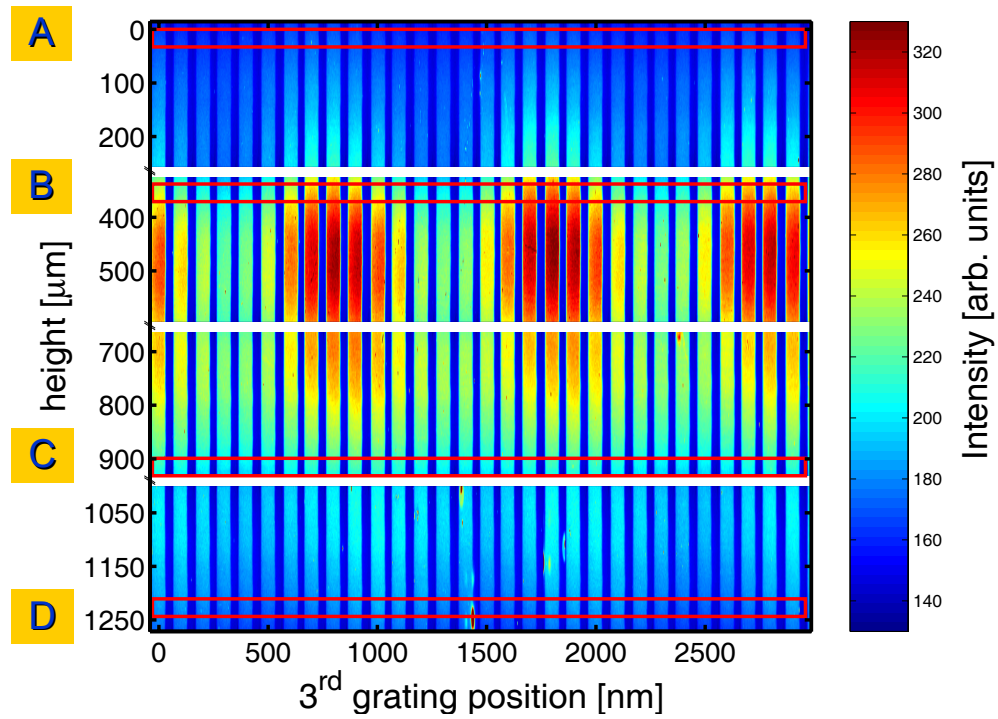




Mechanically Magnified Fluorescence Imaging



A Porphyrin experiment (TPP)



New Journal of Physics (11/2005).

Advantages of Mec(anically) Mag(nified) Imaging:

Scalability !

- The efficiency improves with particle size!

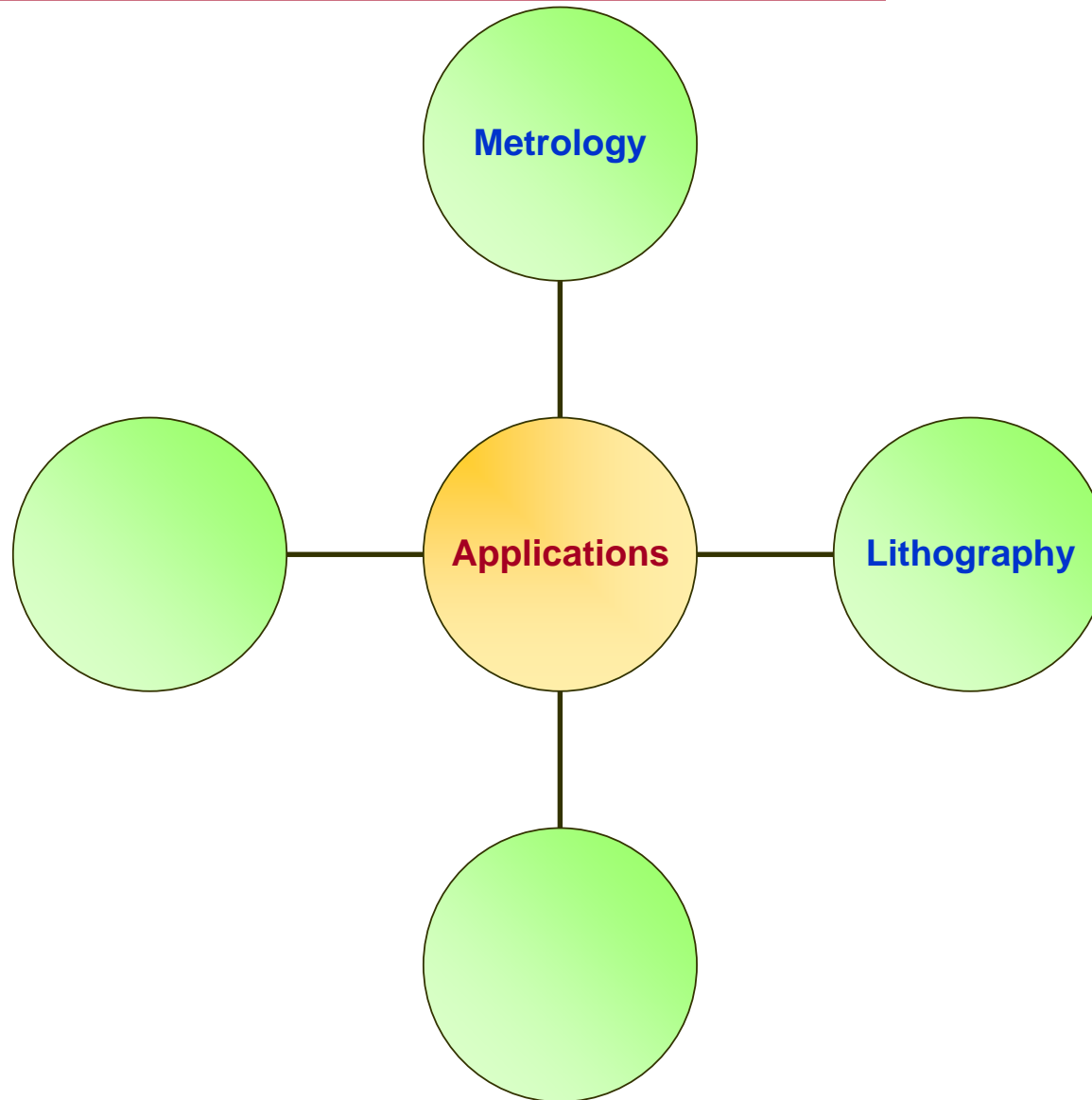
Horizontal surface position

- Encodes grating position
- Magnification arbitrarily large, here 4500 x
- ‚Immune‘ to surface diffusion

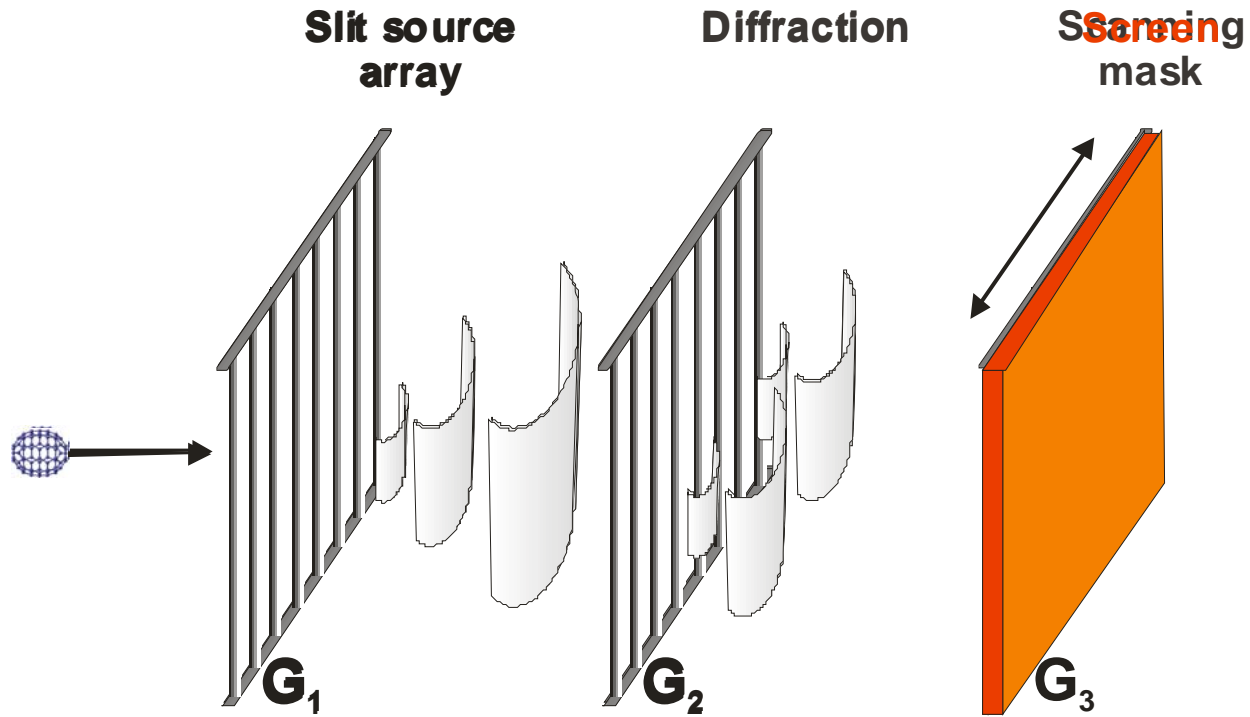
Vertical surface position

- Encodes molecule velocity
- Simultaneous recording of all velocities: extreme stability
- Favorable for distinguishing quantum from classical fringes

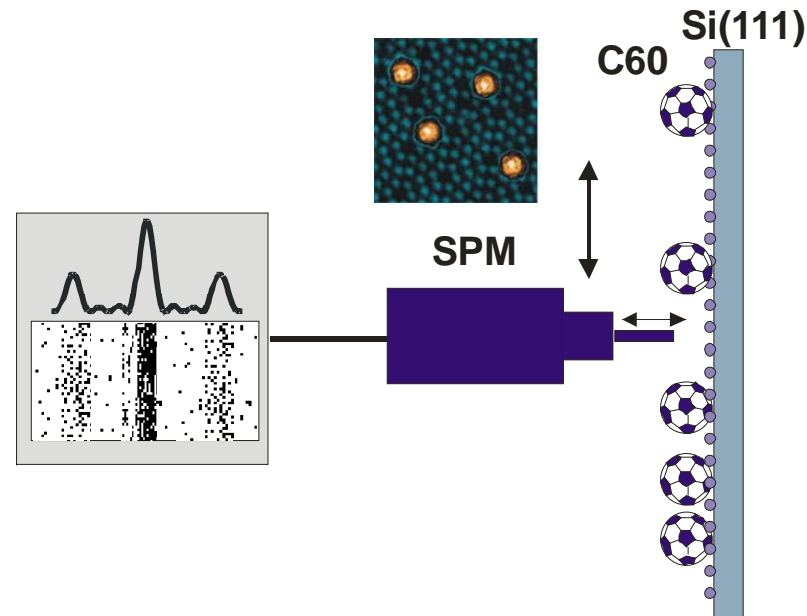
Applications being explored...



**Deposition of Interferograms:
Molecular Nanopatterns (in preparation ...)**

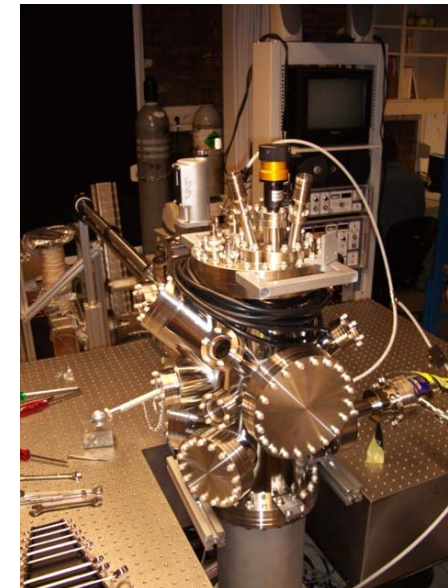


From curiosity to curious applications ?!

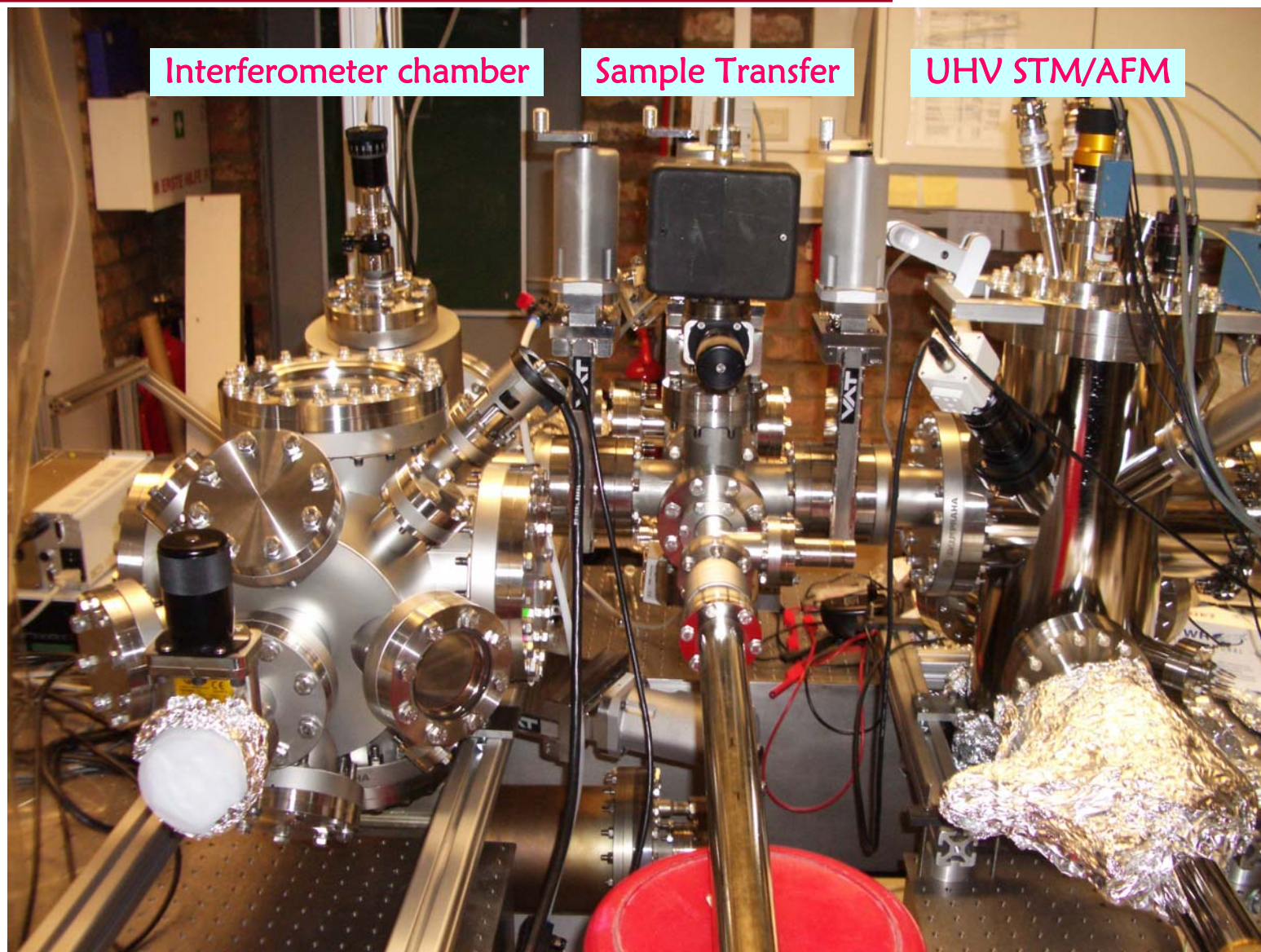


- Structures with down to 50/100 nm features/periods
- Composed of single (functional) molecules (1- 10 nm sized)
- Identified, post-processed with Scanning Probe Microscopy
- Non-trivial patterns with added grating motions & new masks

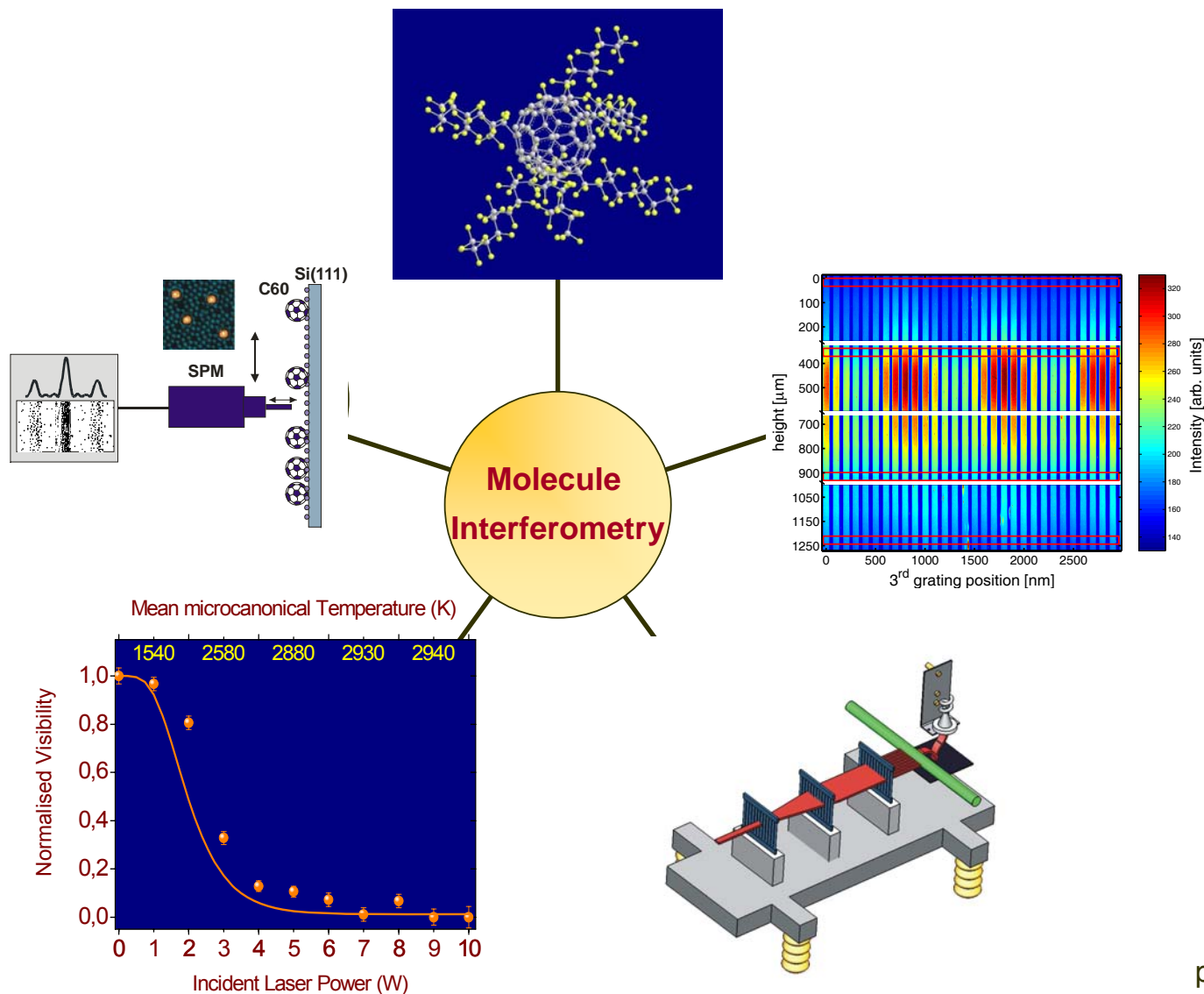
Mounting of the new Nanoimaging/fabrication lab



Vacuum setup completed ... STM/AFM being tested



Summary & Outlook



The Vienna team on Molecular Quantum Optics



M. Arndt



L. Hackermüller



A. Major



A. Stefanov



H. Ulbricht



A. Zeilinger



S. Deachapunya



A. Stibor



E. Reiger



M. Berninger



S. Gerlich



G. Kiesewetter

Former postdocs:

- Fabienne Goldfarb
- Klaus Hornberger
- Björn Brezger

Former PhD:

- Olaf Nairz

Former Diploma students

- Julian Voss Andreae
- Julia Petschinka
- Stefan Uttenthaler