
Research with Photons
Stefan Eisebitt, Max-Born-Institut Berlin

# Synchrotron Radiation Users

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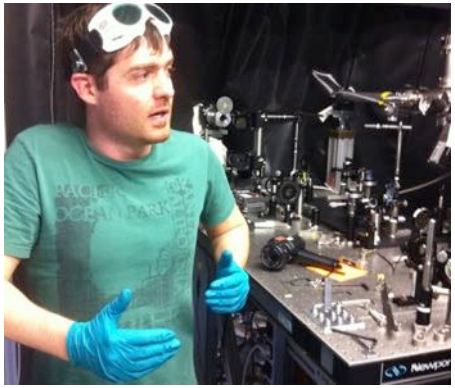
**Large German Community**

- approx.. 4000 User p.a. in Germany
- approx. 50% Young Researchers: B.Sc./M.Sc./Ph.D. Students
- many university groups, close cooperation with facilities

**Huge Scientific Diversity, including e.g.**

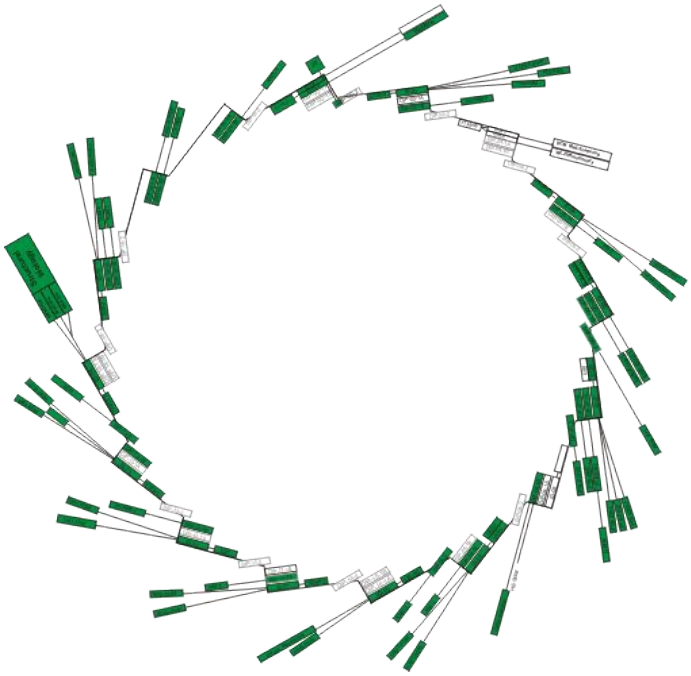
- Life Sciences
- Nanoscience- and Technology
- Material Science
- Environmental and Geosciences
- Physics, Chemistry, Engineering Science





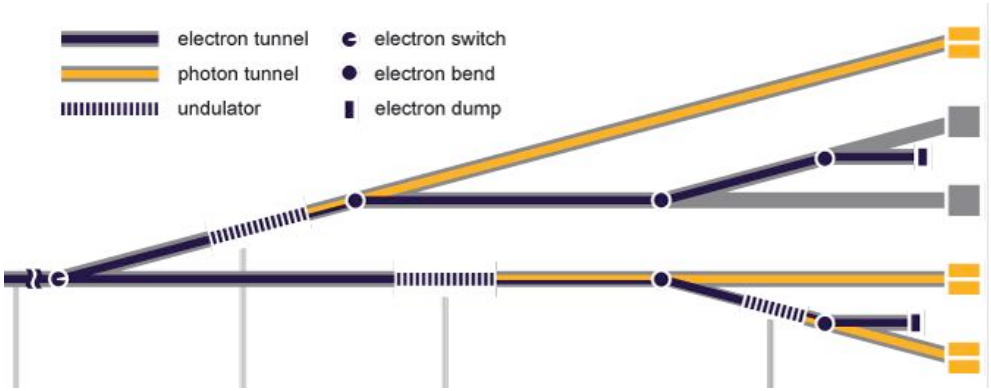

# Differentiation within SR Community

**Ring**



- smaller teams
- many „non-SR-experts“
- measurements: routine to cutting edge

**FEL**




- large, multinational teams
- mostly expert driven
- cutting edge, terra incognita

**Different research topics. Complementary sources.**

# One Community, different foci and tools

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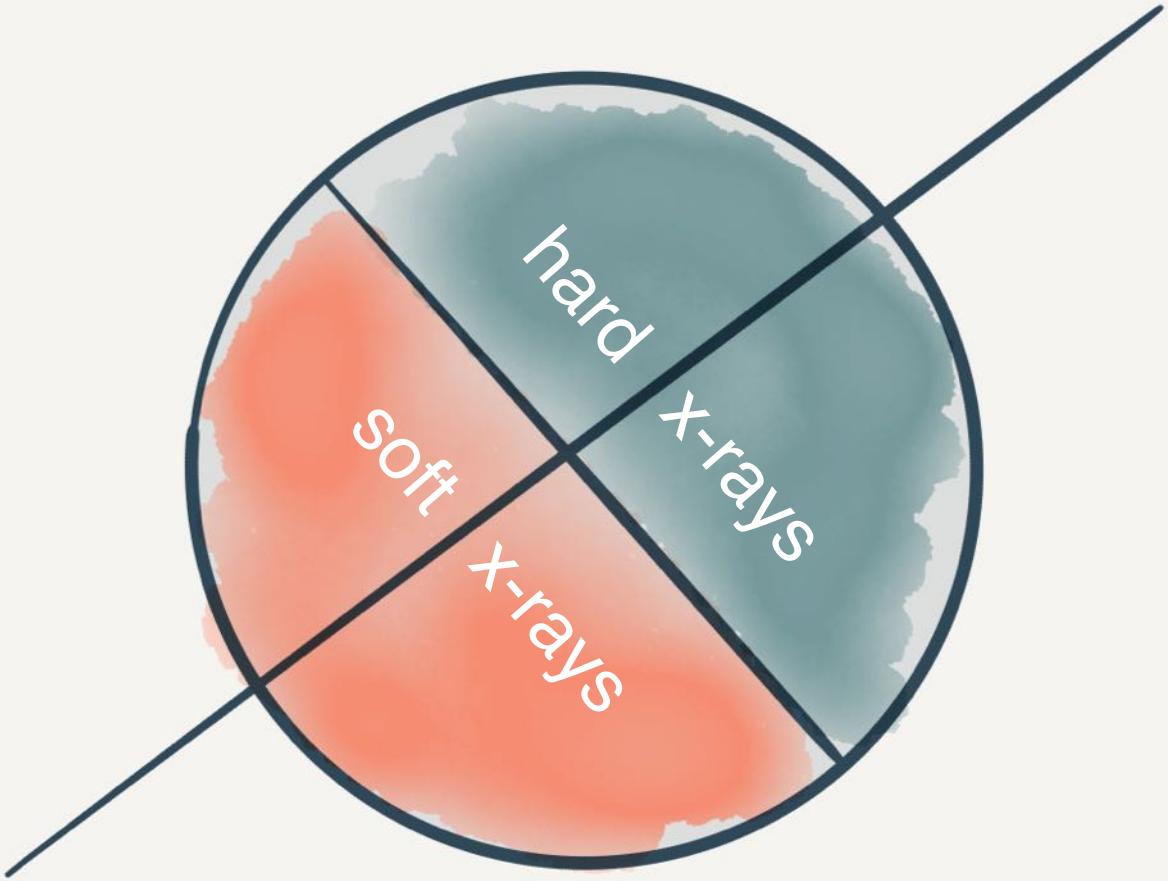
## Storage Rings




## Free Electron Lasers

# Focus Areas (KFS outlook, 2015)

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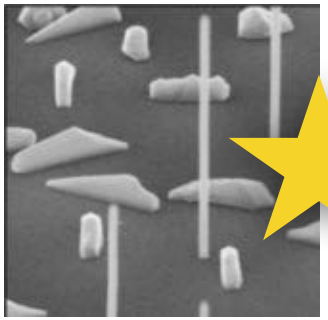
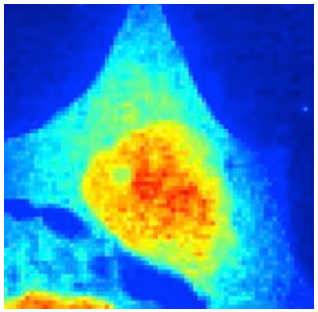
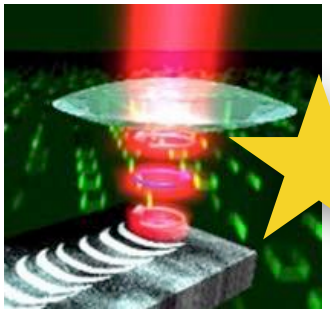
**Understand Function from the Structure and Dynamics. Tailor Functionality.**
Hierarchic, on the different relevant time and lengthscales.



**Material Properties & Engineering Materials**
From the investigation of fundamental physical and chemical causalities to the knowledge-based optimization of materials e.g. for nanotechnology, microelectronics and new functional materials.



**Life and Environmental Sciences**
From the determination of static structure and processes on atomic and microscopic scale to to new solutions for problems in society.



**Dynamic Processes and Interaction of Matter with intense Radiation**
Clarification of fundamental interactions and exploration of resulting means of manipulation.

# Some Perspectives (to some extent my personal view)

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**Storage Rings:**

- Nanoscale information (focussing, imaging)
  → high brightness, diffraction limited beams
- Time resolved information (pump-probe)
  → short pulses, timing modes
- In-situ / in operando experiments
  → complex addl. instrumentation (stable beams)

**FELs:**

- many new topics
- e.g. non-linear x-ray matter interaction
  → laser-like beams
  (wavelength, pulse energy, pointing, pulse profile)
- e.g. fast & short range excitations
  → 2 x-ray pulses, 2 colors

# 2 Examples: Pump-probe Holography (no details)

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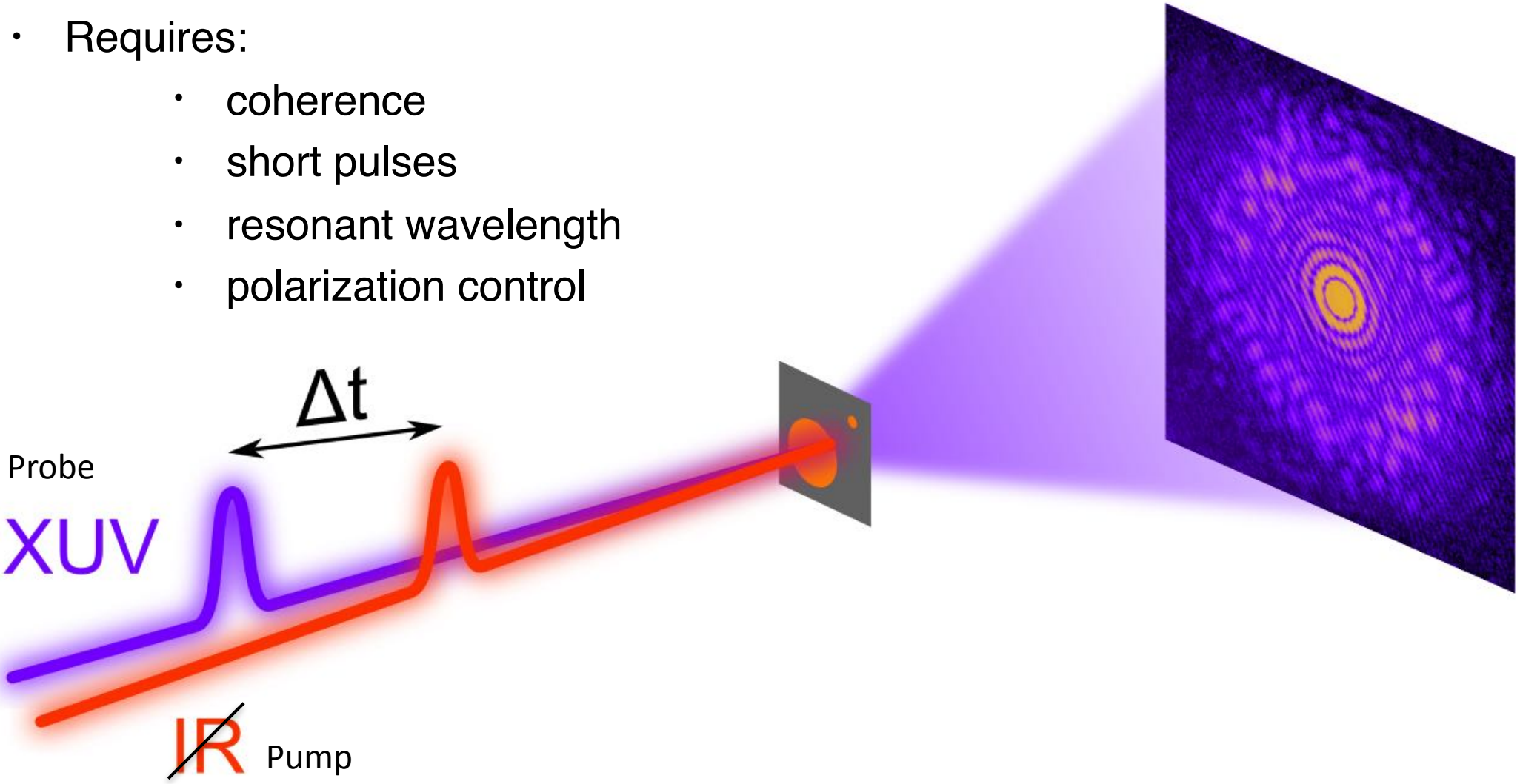
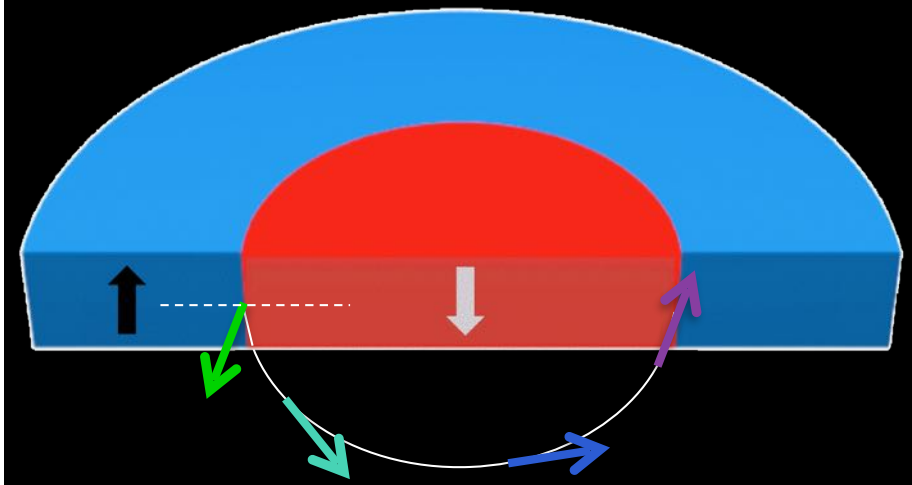
- Nanoscale Information
- Study of dynamic processes
- Requires:
  - coherence
  - short pulses
  - resonant wavelength
  - polarization control




1. experiment: pump = magnetic field

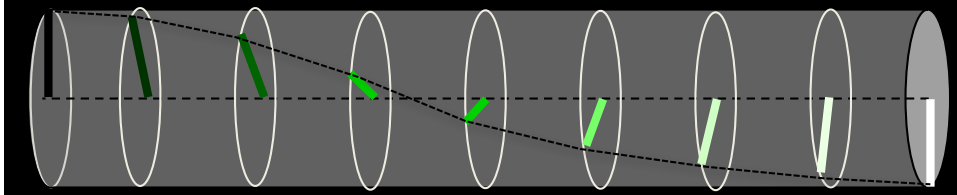
# ns, ps @ Synchrotron (BESSY II)

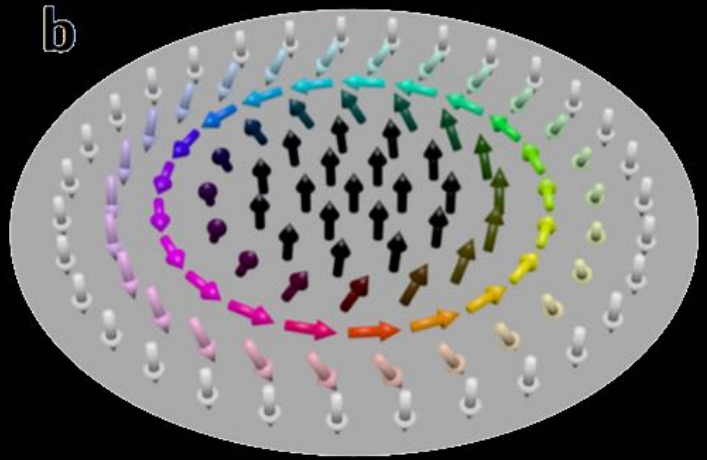
# A magnetic bubble is a Skyrmion

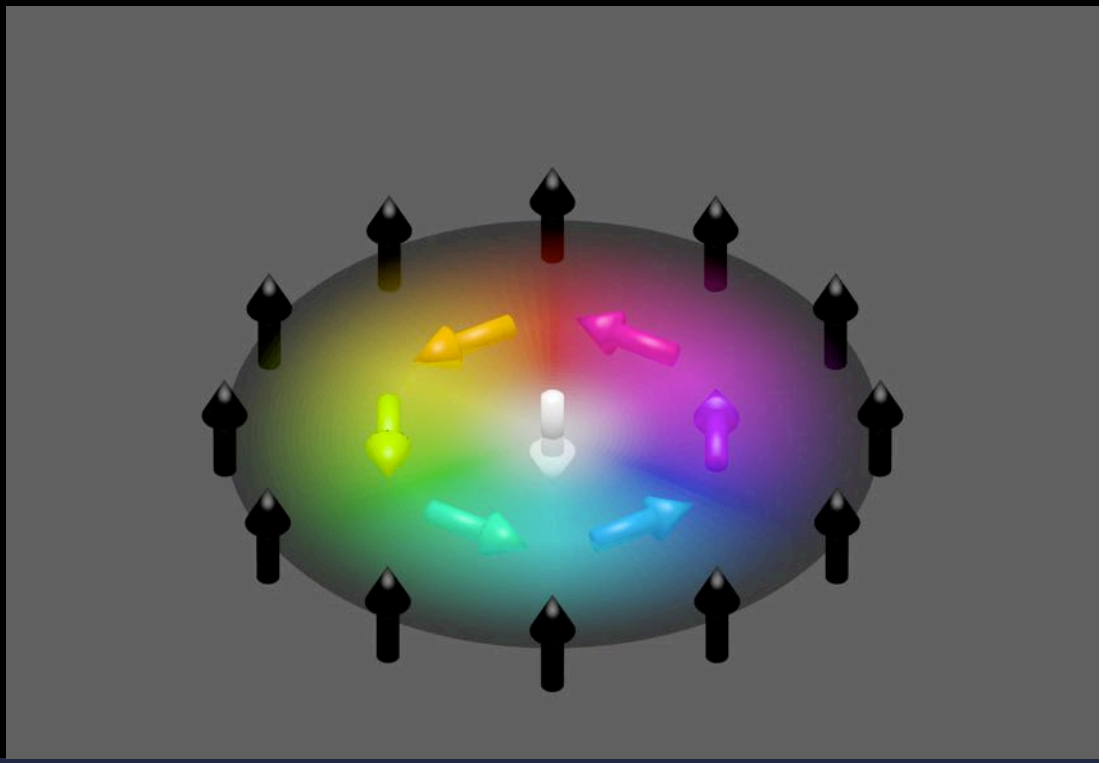


Magnetic Bubble
with Bloch wall

in a thin film with perpendicular magnetic anisotropy





# Skyrmion Racetrack Memory

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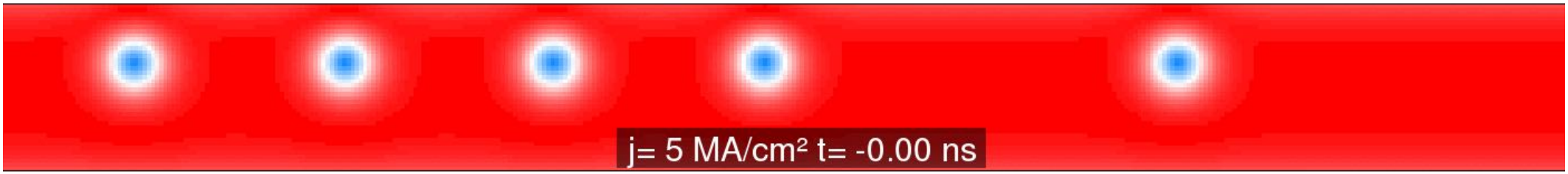
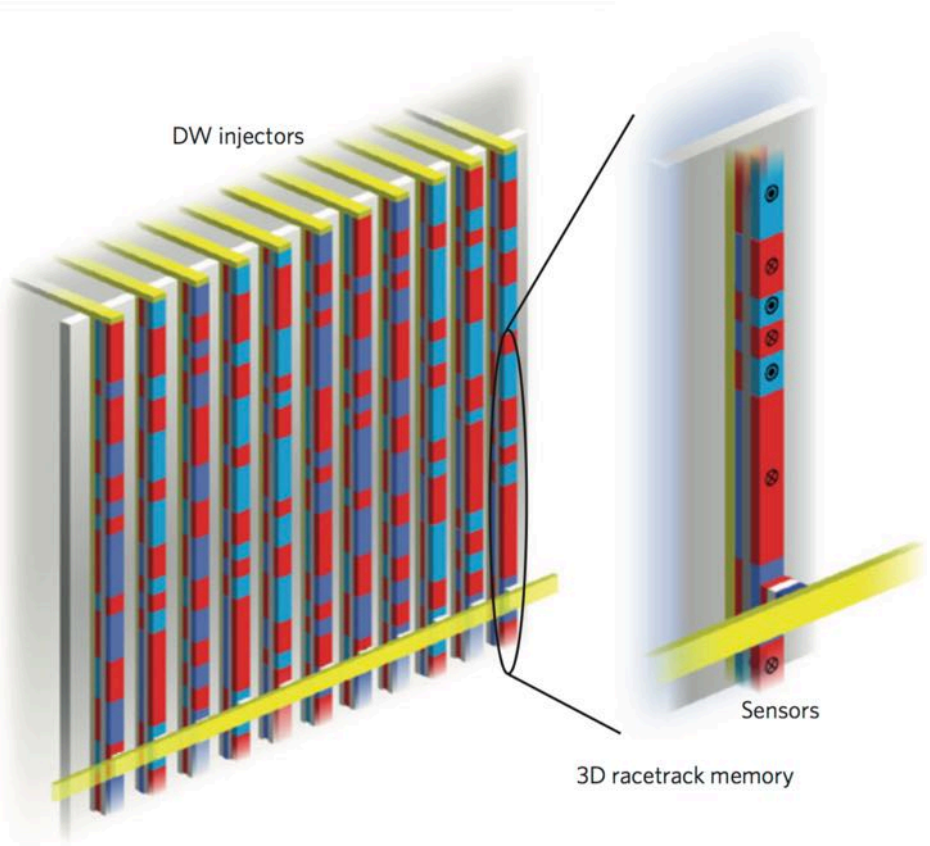
- Skyrmions can be moved in wires, e.g. via Spin-Hall Effect (here: Simulation)




*A. Fert et al. Nature Nanotechnology* **8**, 152–156 (2013)

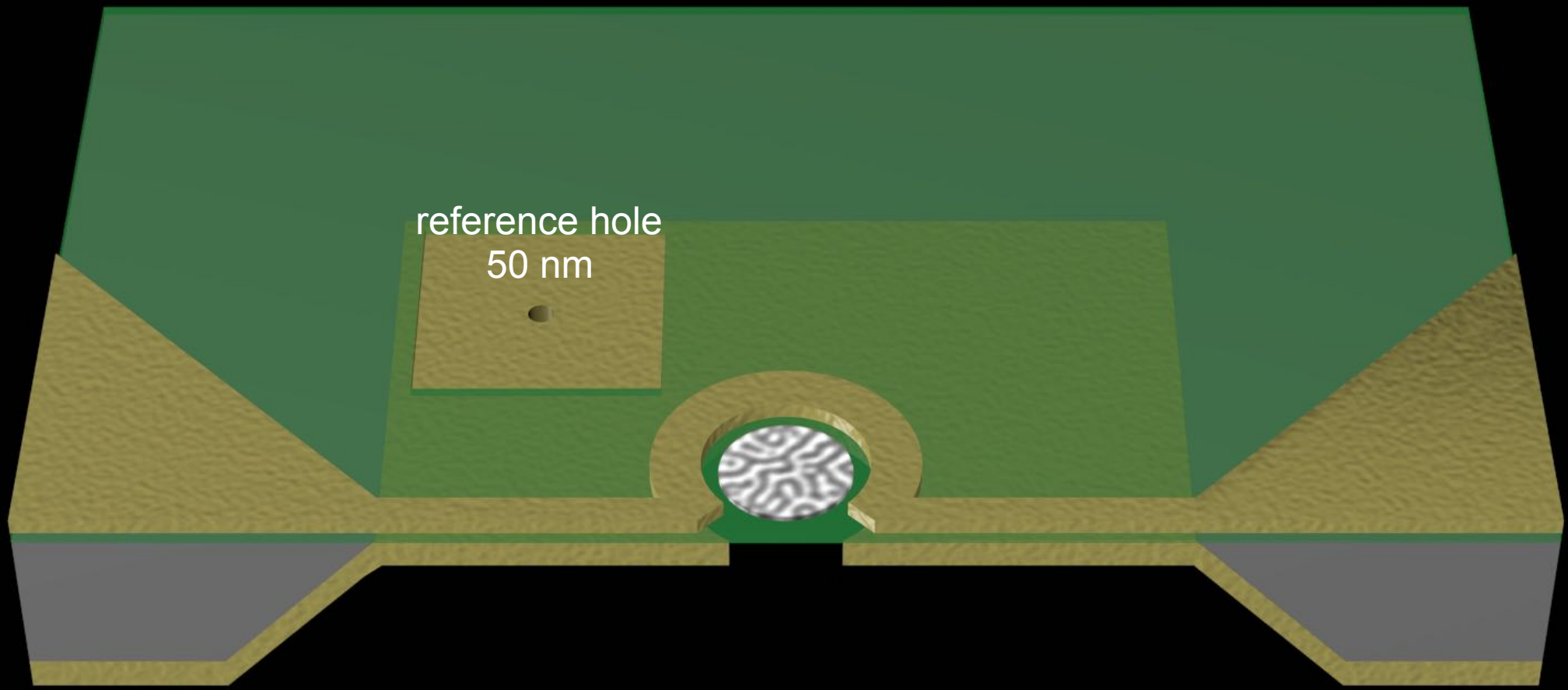
- Racetrack memory concept
  → 3D integration possible




*S. Parkin & S.-H. Yang Nature Nanotechnology* **10**, 195–198 (2015)

# B-pump X-probe FTH: sample design

Investigation of domain wall motion in response to magnetic field pulses



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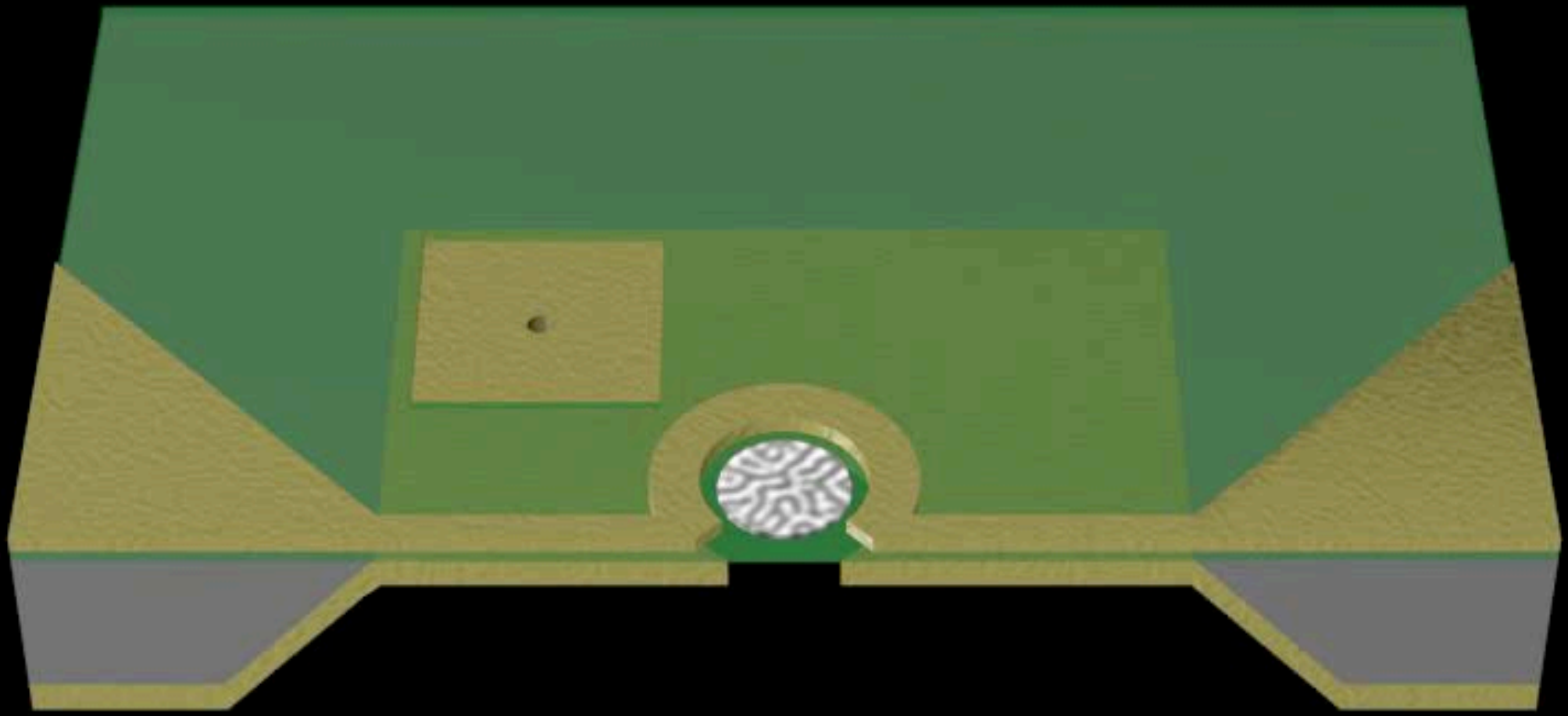


requires: coherent photon flux ∝ Brightness * $\lambda^2$

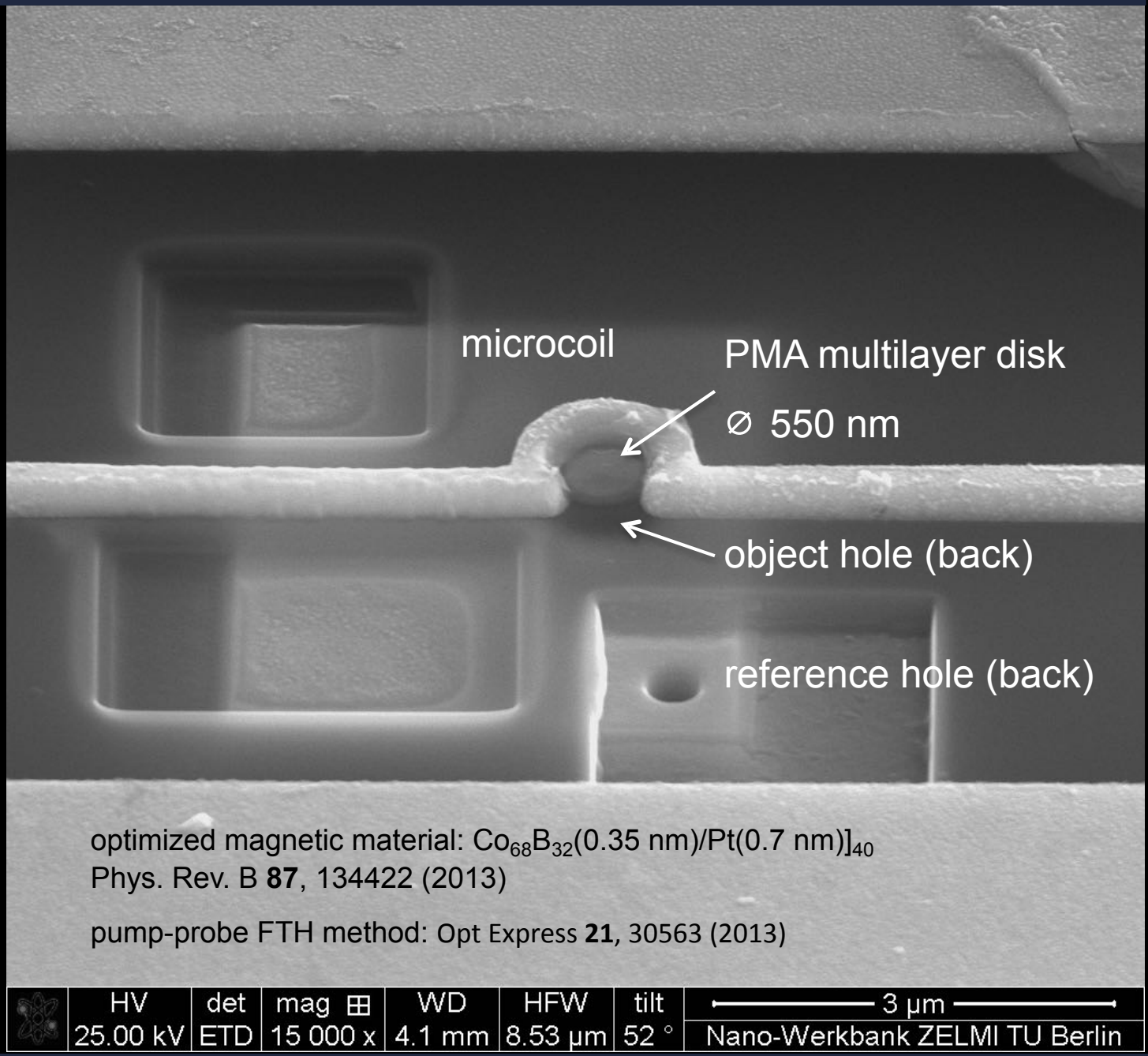
# Pushing Magnetic Bubbles

## Sample & FTH Geometry

current pulse

pump-probe
via FTH

BESSY II
single bunch



# Observation of gyrotropic motion

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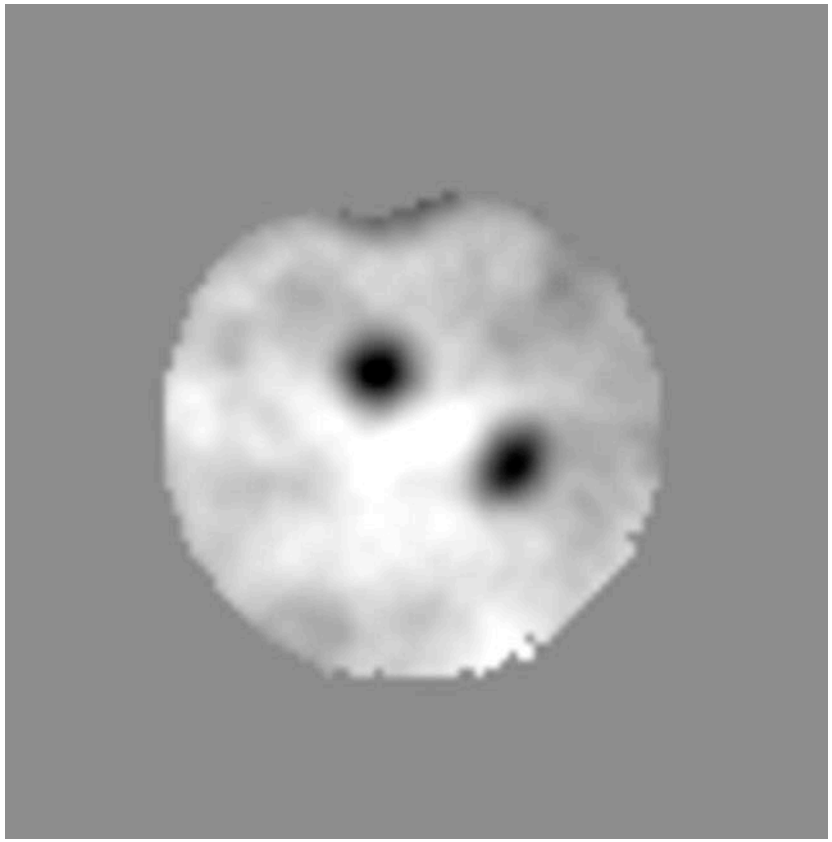
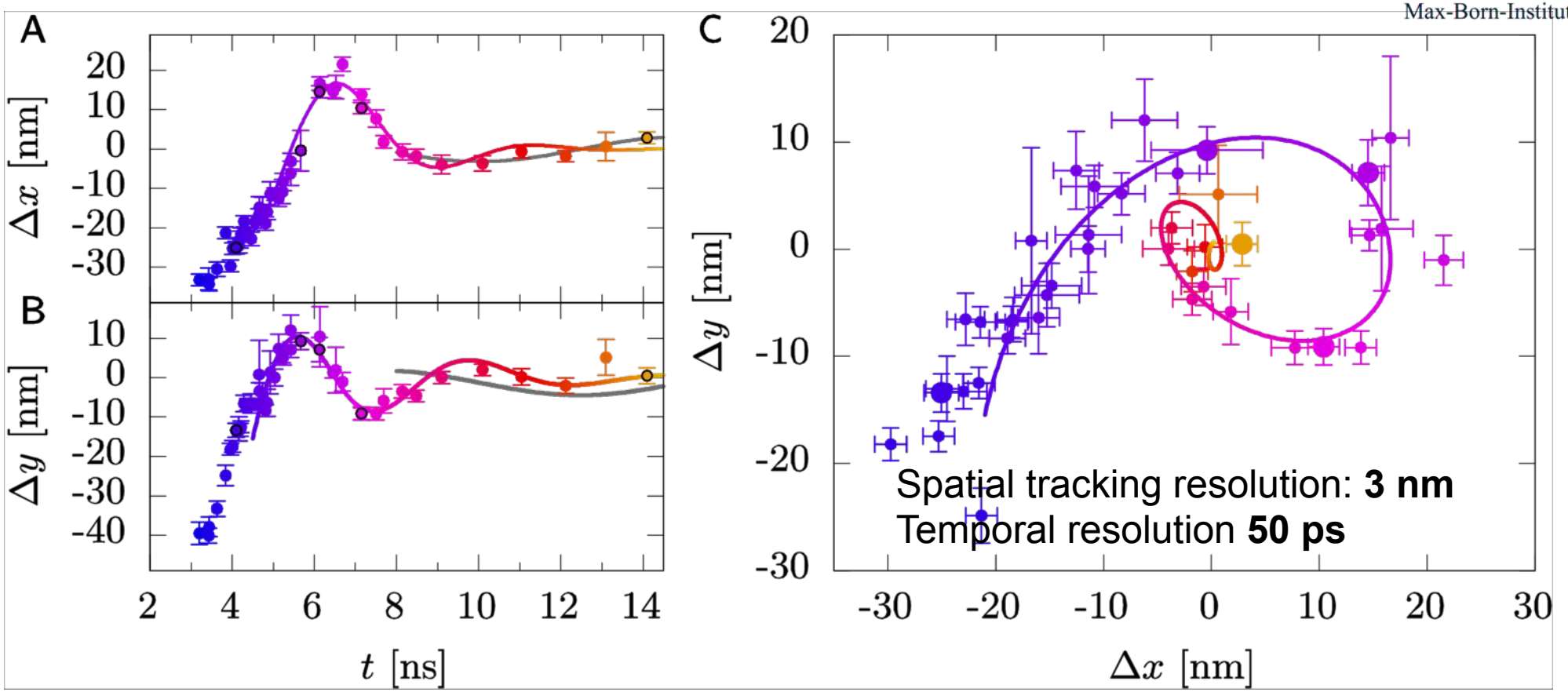
⌀ 550 nm

- Prepare Skyrmion state in external magnetic field (-125 mT)
- Bipolar field pulse ( ± 35 mT pulse, 3 ns): generate & annihilate 3rd domain
- Skyrmion is displaced from equilibrium position in response to the stray field
- Relaxation through circular trajectory → gyrotropic motion



F. Büttner et al., Nature Physics **11**, 225 (2015)

# Determination of Skyrmion mass from trajectory



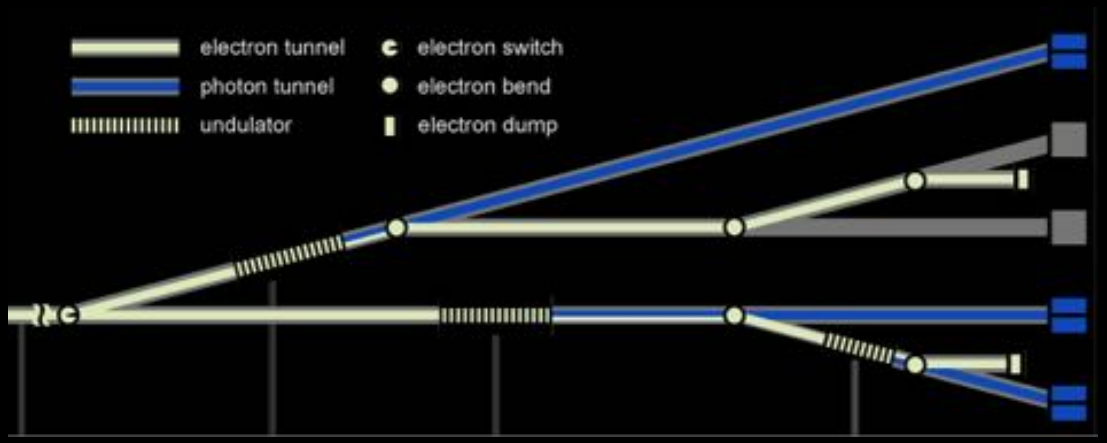

2-frequency fit:

CCW: 1.00 (13) GHz
CW: -1.35 (16) GHz

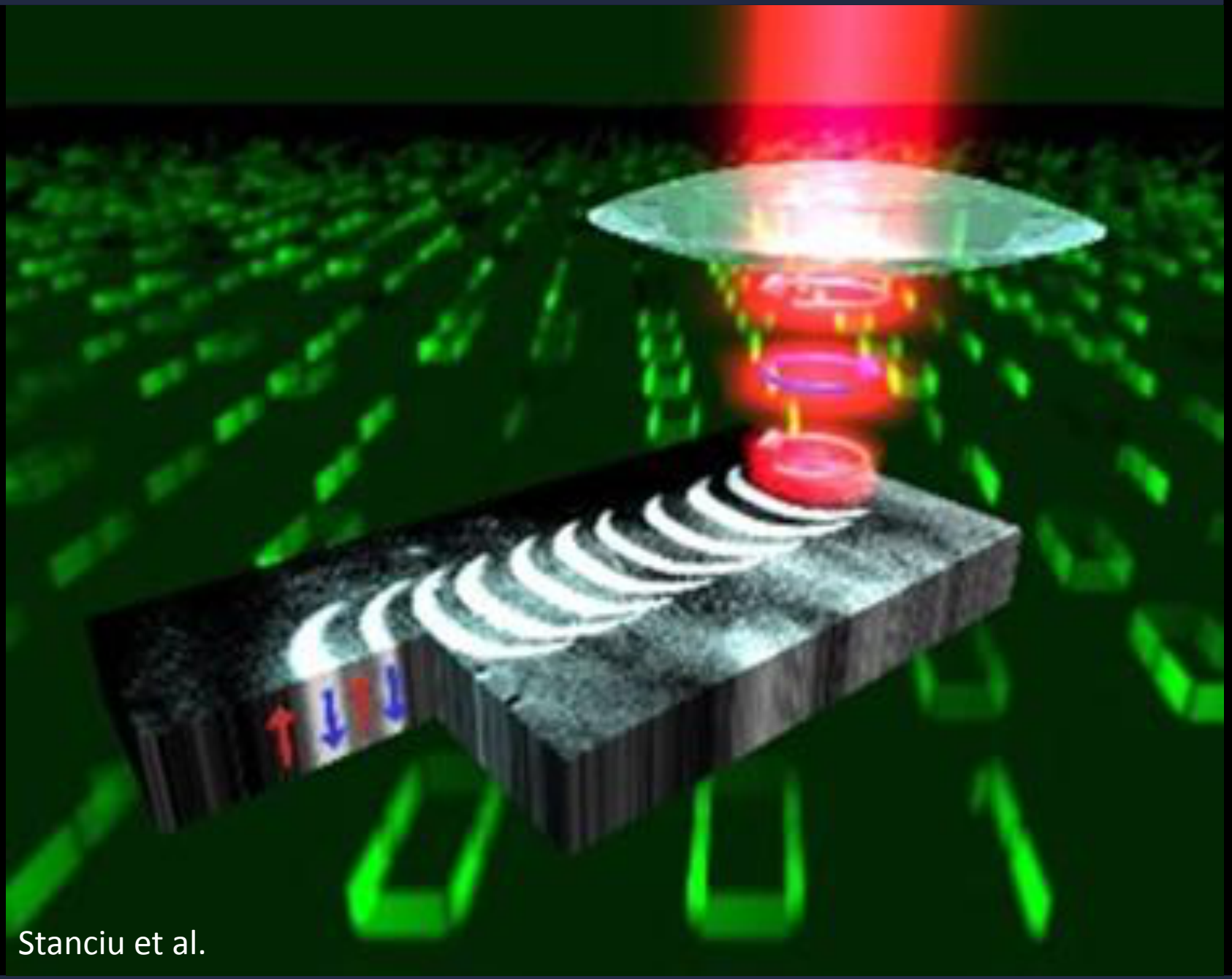
- existence of eff. mass experimentally confirmed
- large compared to other mag. quasi particles
- topological origin (breathing mode)

F. Büttner et al., Nature Physics **11**, 225 (2015). — work in collaboration with AG Kläui

# fs @ FEL (FERMI)

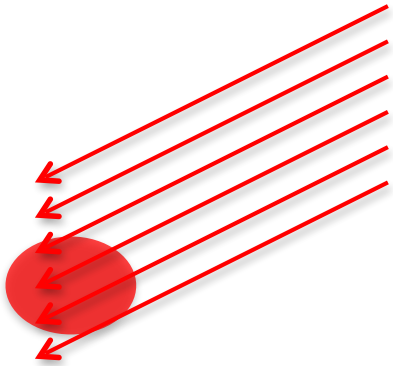

electron tunnel
photon tunnel
undulator
electron switch
electron bend
electron dump

# All-optical data writing



Stanciu et al.

# IR-pump X-ray holography probe



**E**-field enhancement via standing wave




@ FERMI, DiProI

# Seeing demagnetization proceed in time and (real) space

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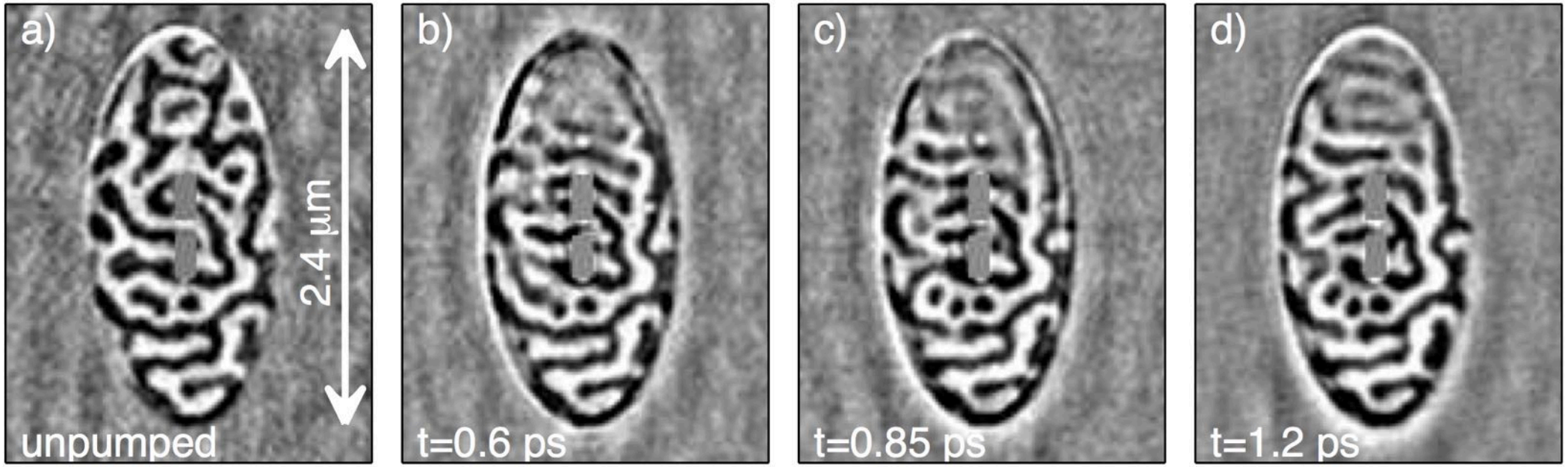
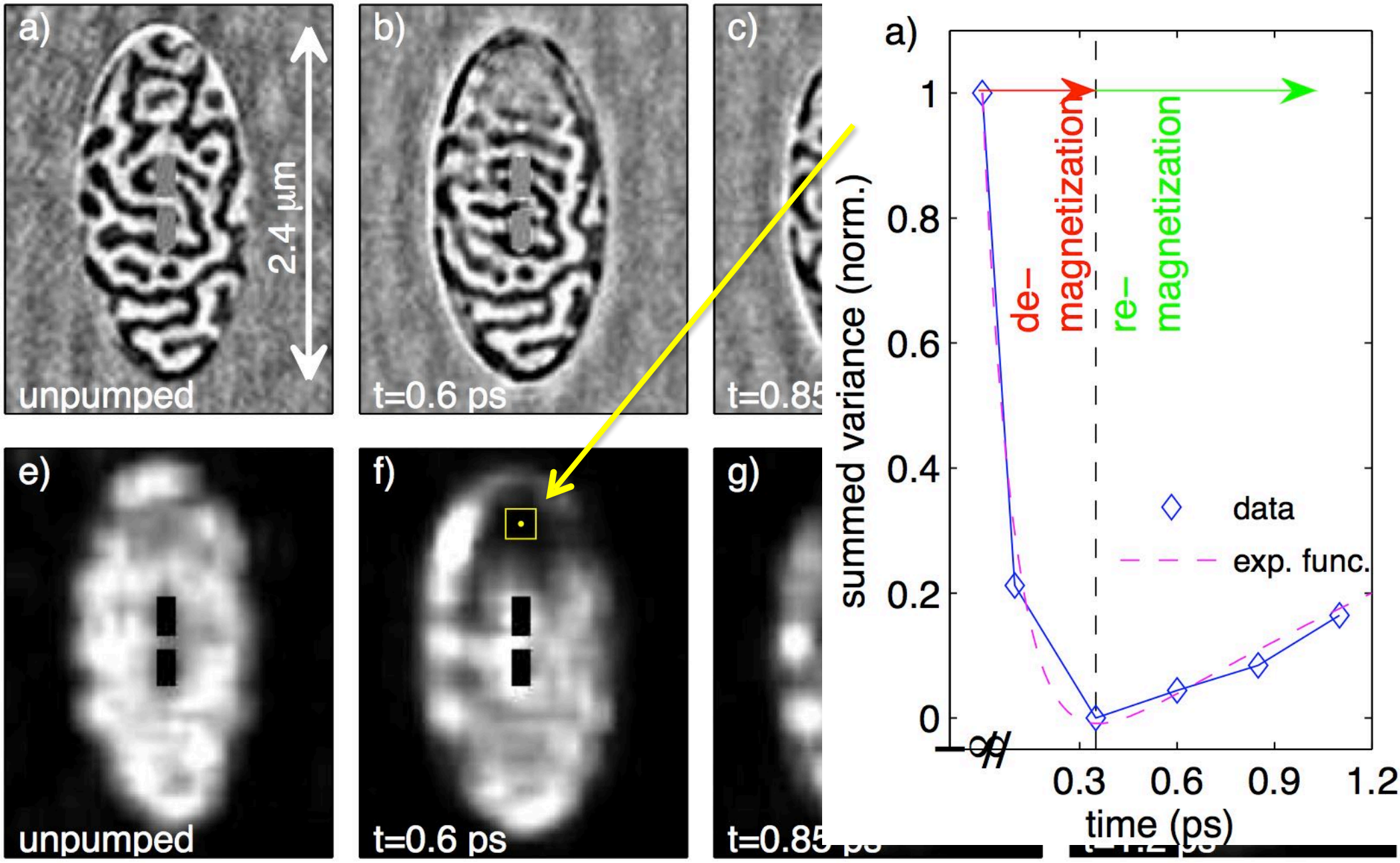
IR-pump FTH-probe @ FERMI




- First ever images of non-local demagnetization (3500 shots per image)
- Demagnetization propagation front moves at 0.2 nm/fs, consistent with spin transport
- Some irreversible changes in domain pattern

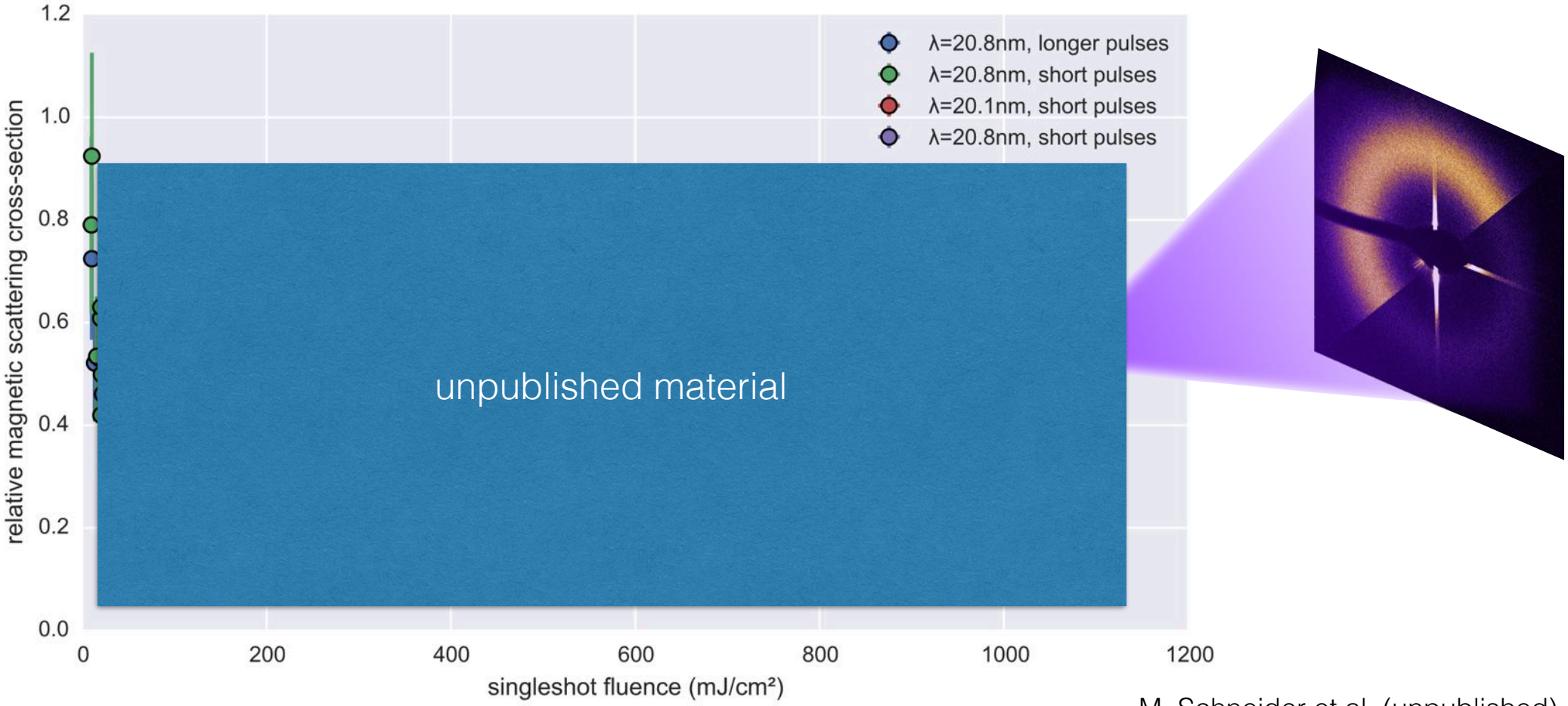
C. Von Korff Schmising PRL **112**, 217203 (2014)

# Local variance as a measure of M



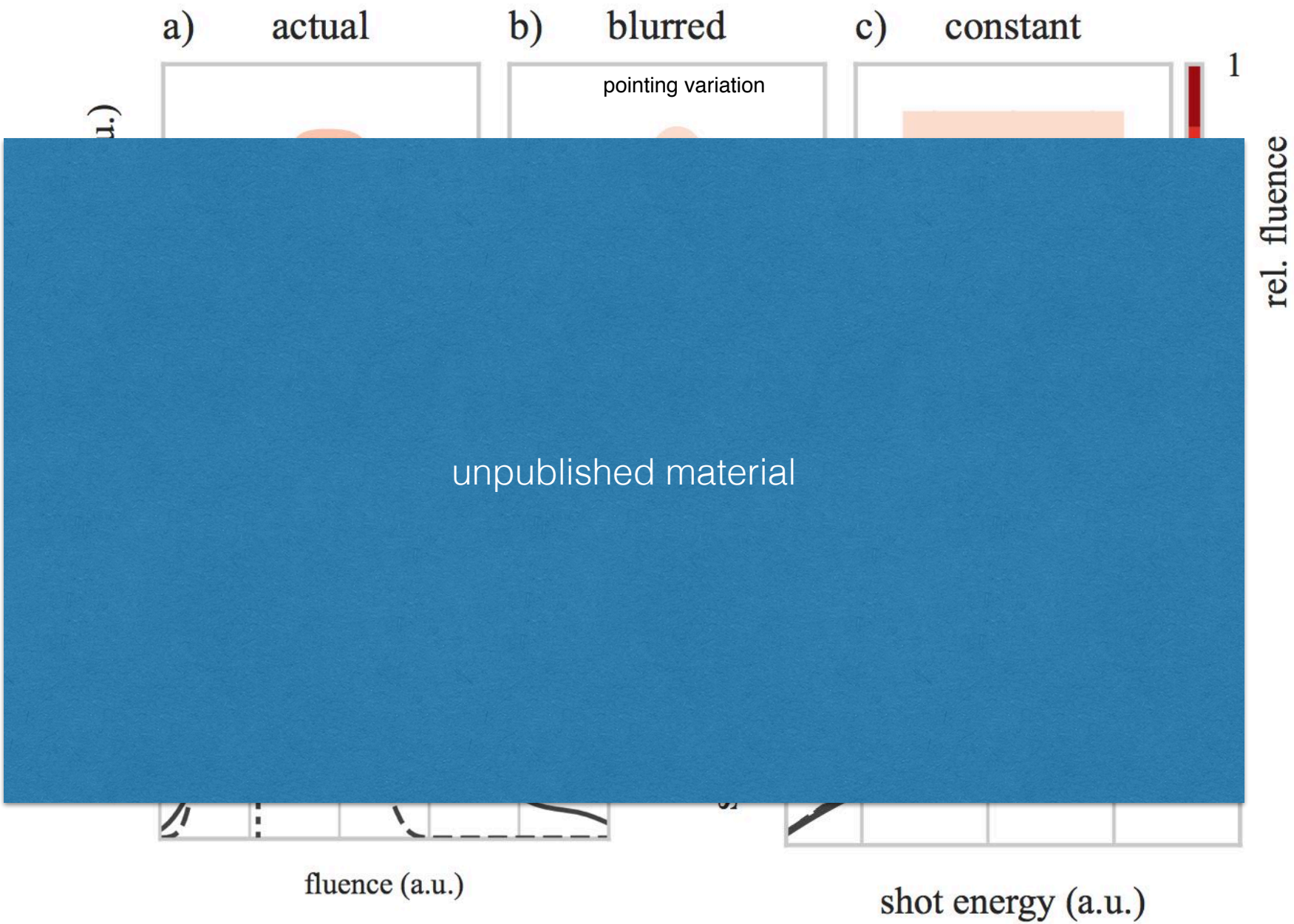
# x-ray matter interaction

- resonant magnetic scattering cross-section depends on x-ray fluence
- potential explanations: shift of resonance energy, electronic bleaching, stimulated emission, …




M. Schneider et al. (unpublished)

# I(r) on the actual sample




M. Schneider et al. (unpublished)

# Issues

- short time scale ( Auger < 1 fs)

  → FEL pulse duration

- well defined x-ray spot on sample (nonlinear process!):

  → λ, I(r)

- 2 x-ray pulses λ1, λ2 at Δt would be helpful

  → x-ray optics vs. accelerator-based

# Some Perspectives (my personal view)

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  → **high brightness**, diffraction limited sources
- Time resolved information (pump-probe)
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- e.g. non-linear x-ray matter interaction
  → **laser-like beams**
  (wavelength, pulse energy, pointing, pulse profile)
- e.g. fast & short range excitations
  → **2 x-ray pulses, 2 colors**
- pump lasers (or 2nd x-ray pulse) are as important as FEL beam
- Solids: few femtoseconds, AMO: attoseconds