A closer look: mean-field theory

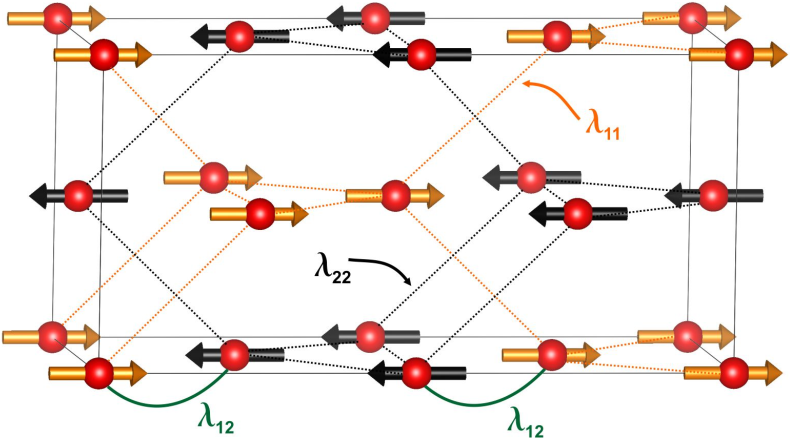
Curie-Weiss temperature, spin-flop transition

generation of magnetic fields

helical magnets

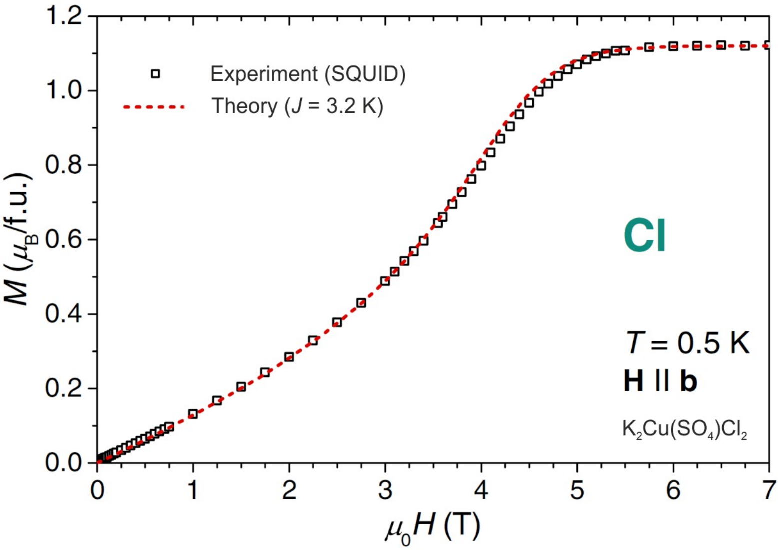
by Alexander Tsirlin, Leipzig University

Lecture 6: November 25, 2024

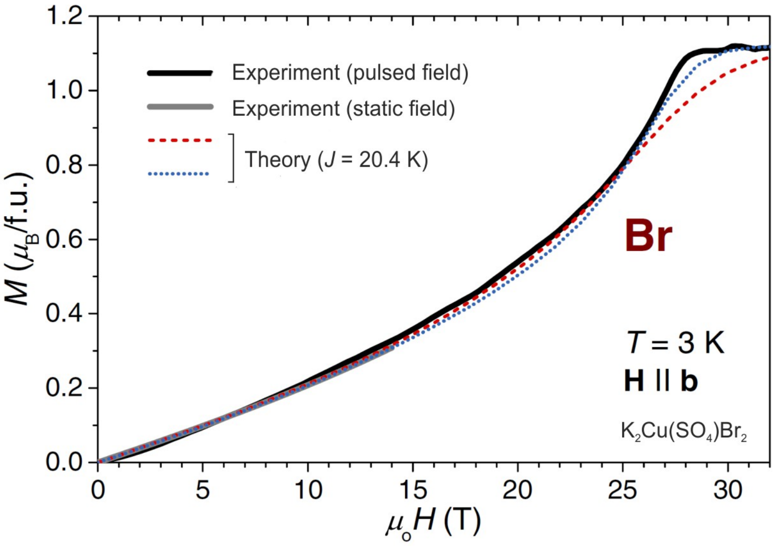


λ_{11}, λ_{22} – interactions within the sublattice

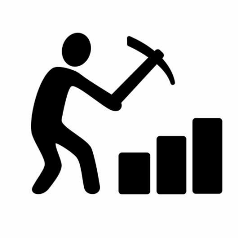
$\lambda_{12} = \lambda_{21}$ – interactions between the sublattices



Phys. Rev. B 90, 174413 (2014)



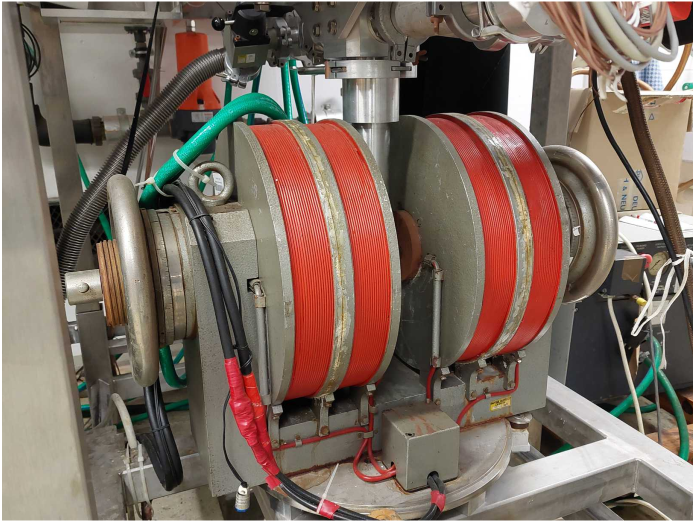
Phys. Rev. B 90, 174413 (2014)



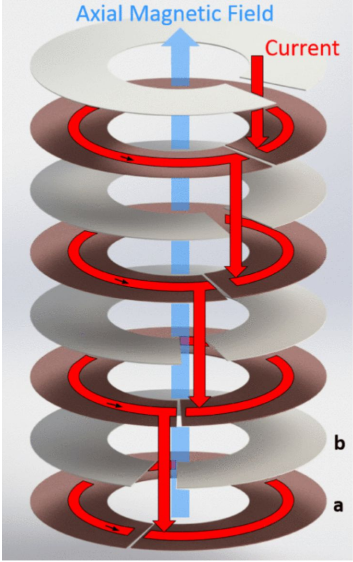
Experiment

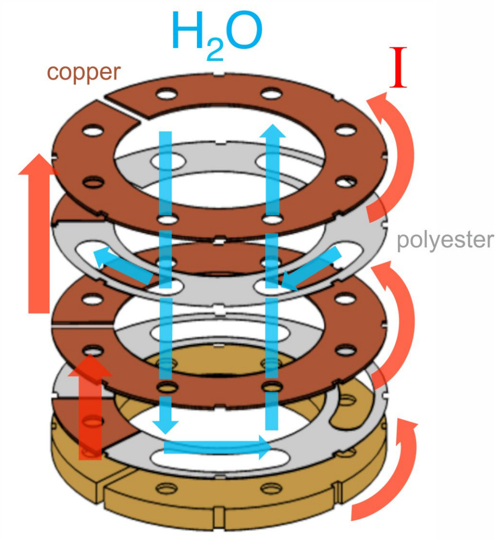
generation of magnetic fields

Standard electromagnet (resistive magnet)

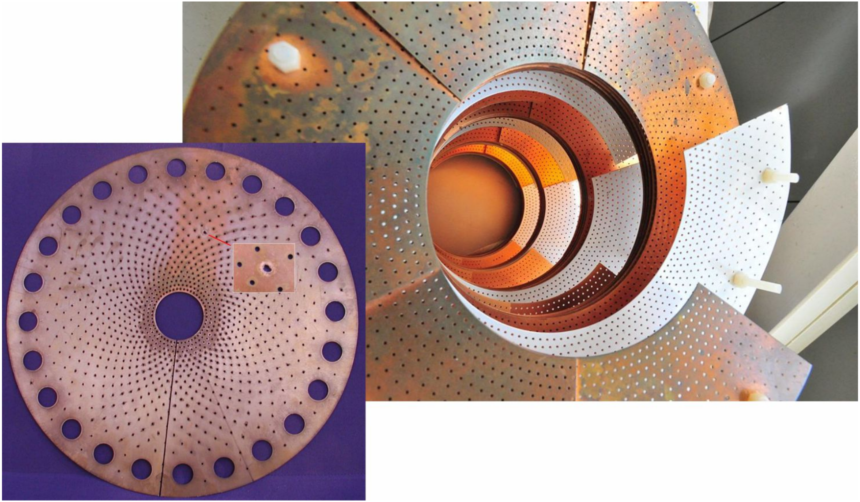


Fields up to 1 T, main usage: electron spin resonance spectroscopy





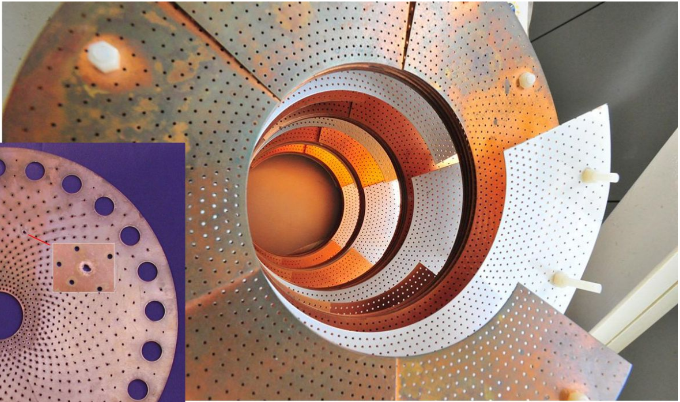
IEEE Trans. Plasma Sci. 44, 540 (2016); Rev. Sci. Instrum. 84, 104706 (2013)

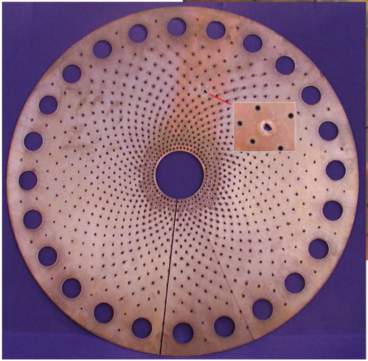


Current record: 35 T (power consumption: 30 MW)
operational costs: $1500 per hour

Image credits: MagLab (fair use) and PeterFrankfurt (CC-zero)

Bitter magnet: pushing the limits





Bitter plate damaged by 20 kA current

Current record: 35 T (power consumption: **30 MW**)
operational costs: $1500 per hour

Image credits: MagLab (fair use) and PeterFrankfurt (CC-zero)

MAGNET ACADEMY
FROM THE NATIONAL MAGLAB

Make It Better ... With a Bitter!

The heart of a resistive magnet, the Bitter disk is too beautiful and versatile to be confined to the laboratory.

Image credits: MagLab (fair use)

Bitter plates re-used

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Zero resistivity, no need for cooling

Commercial magnets: up to **22 T**, prototypes: up to **32 T**
(limited by the critical fields of superconducting materials)

Superconducting magnets

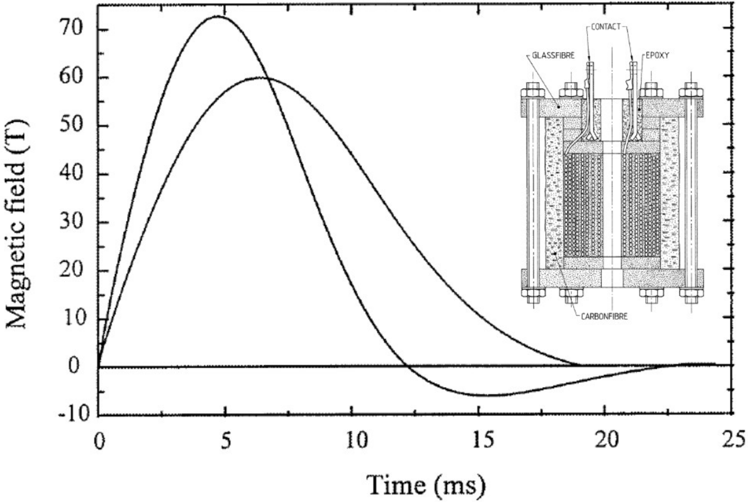
Zero resistivity, no need for cooling

Commercial magnets: up to **22 T**, prototypes: up to **32 T**
(limited by the critical fields of superconducting materials)

Hybrid magnet: **45 T** = 33.5 T resistive + 11.5 T superconducting

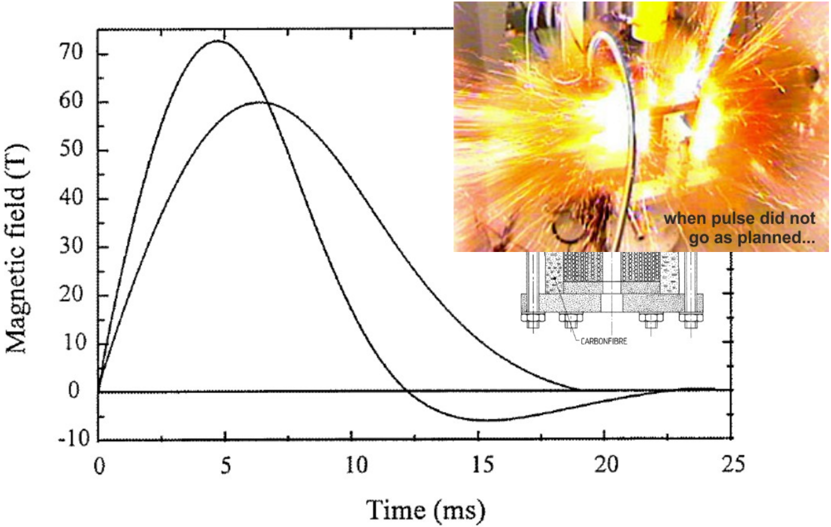
Pulsed magnets: brief shining moments

Rep. Prog. Phys. 62, 859 (1999)



Fields up to 90 – 100 T routinely available, longer pulses possible too

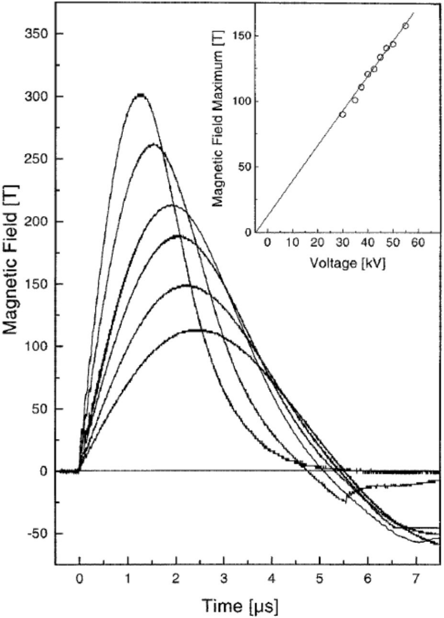
Rep. Prog. Phys. 62, 859 (1999) and MagLab

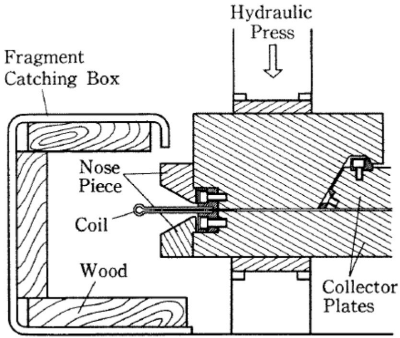


Fields up to 90 – 100 T routinely available, longer pulses possible too

European high-field network (EMFL)

static
pulsed

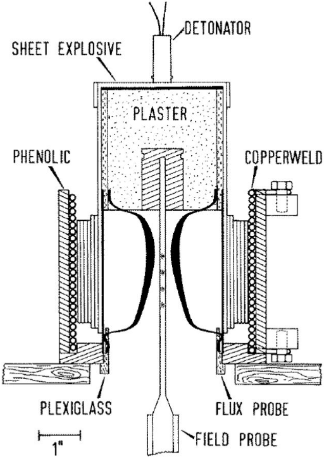


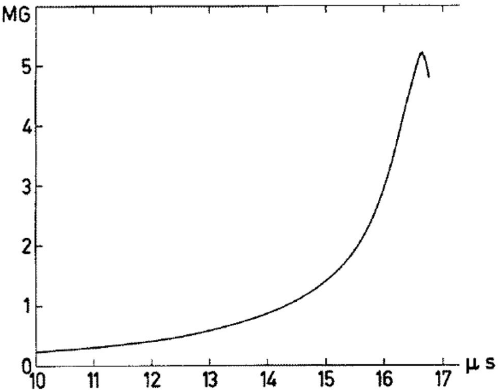


Fields up to 300 T available

Magnetization / magnetostriction measurements (e.g., ISSP Tokyo)

Rep. Prog. Phys. 62, 859 (1999)





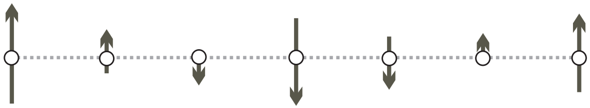
Fields above 1000 T recorded

No real use for condensed-matter experiments (yet?)

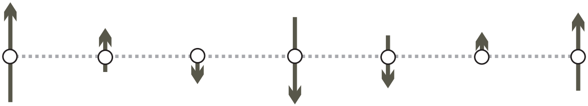
Rep. Prog. Phys. 62, 859 (1999)

Material / Technology

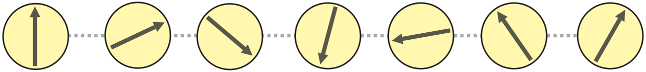
helical magnets



Spin-density wave

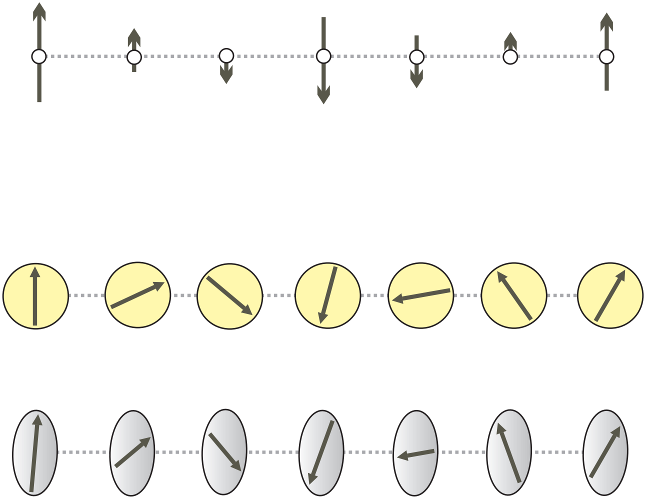


Spin-density wave



Cycloid

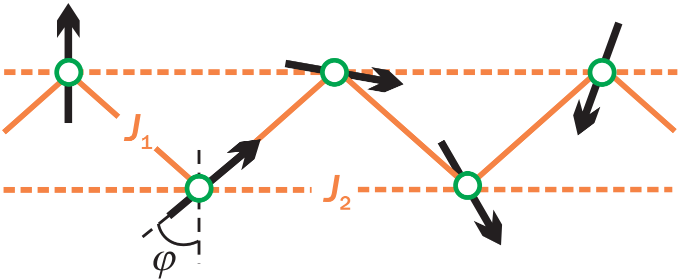
Types of incommensurate magnets

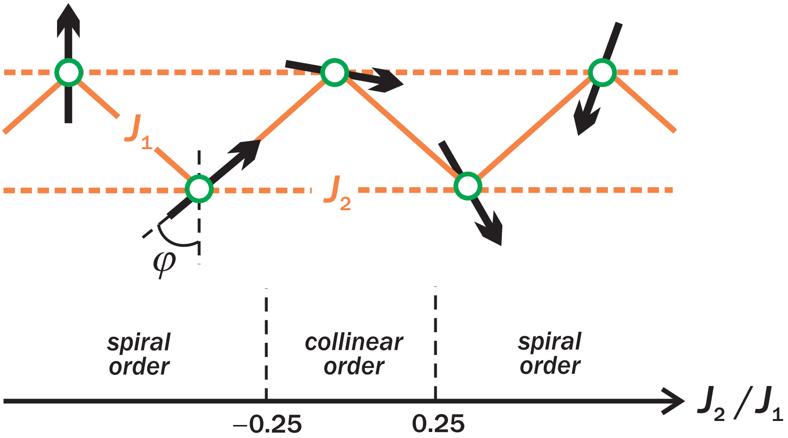


Spin-density wave

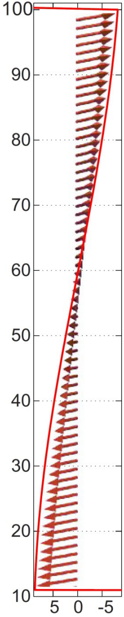
Cycloid

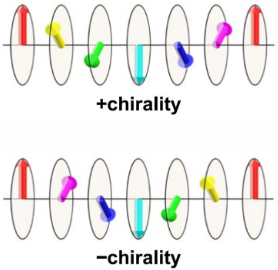
Helix

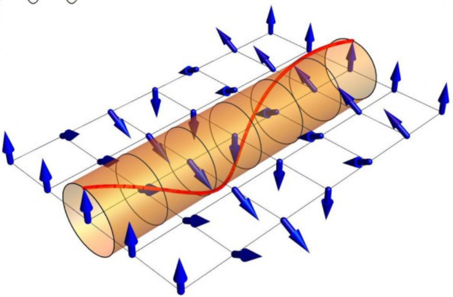

J_1
J_2
φ



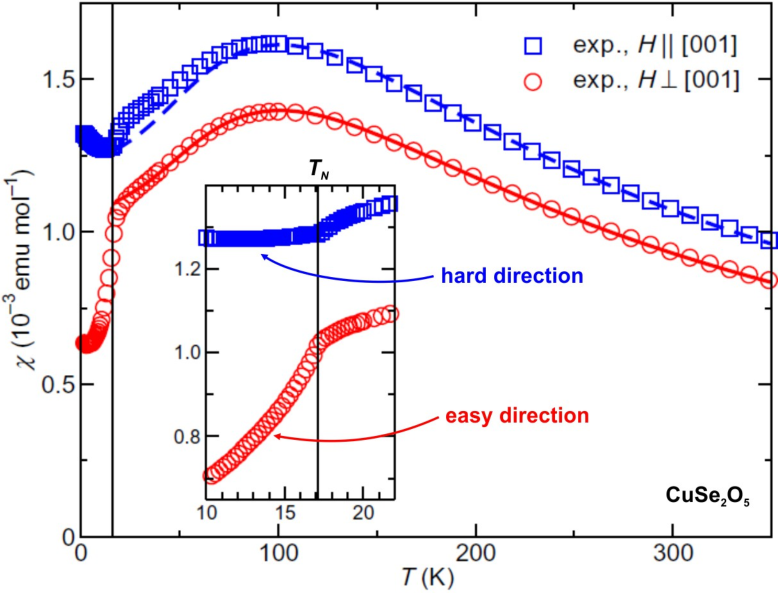
Antiferromagnetic J_2 frustrates the system,
hence spiral order at large enough $|J_2|$



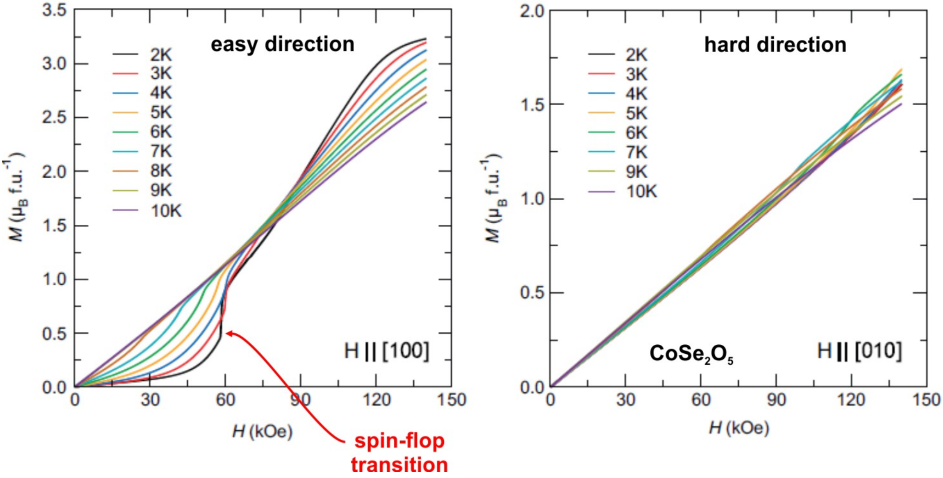




Sci. Reports 5, 16153 (2016); Nature Comm. 15, 1999 (2024); The London Center for Nanotechnology



New J. Phys. 11, 113034 (2009)



J. Solid State Chem. 236, 39 (2016)