Spin-Dipole Oscillation and Polarizability of a Binary BEC

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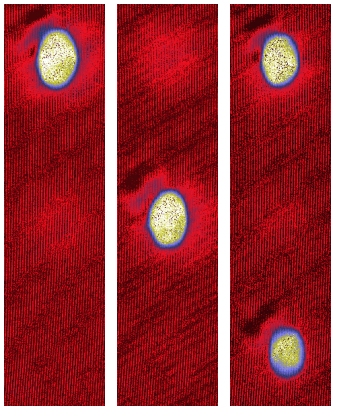
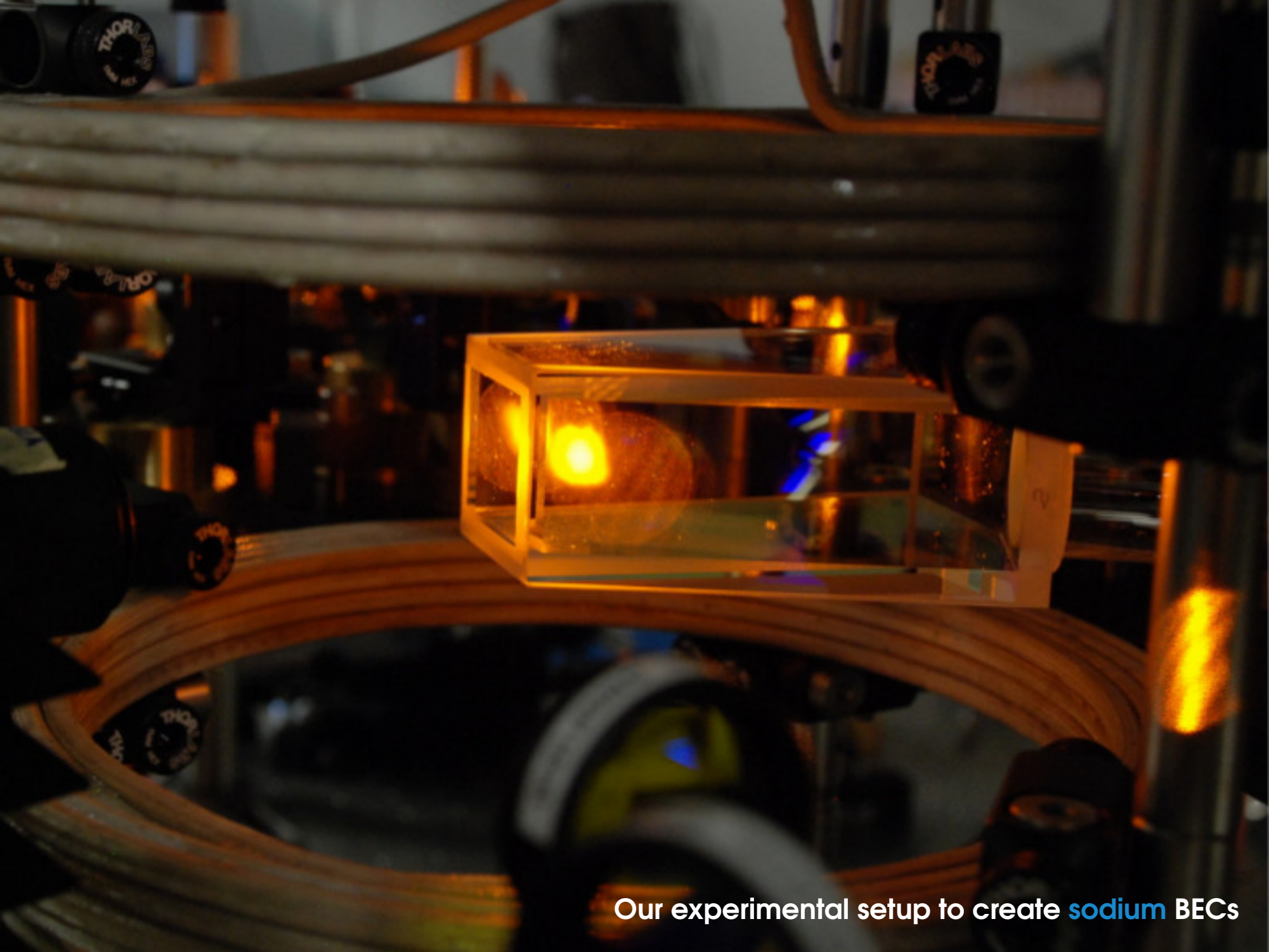
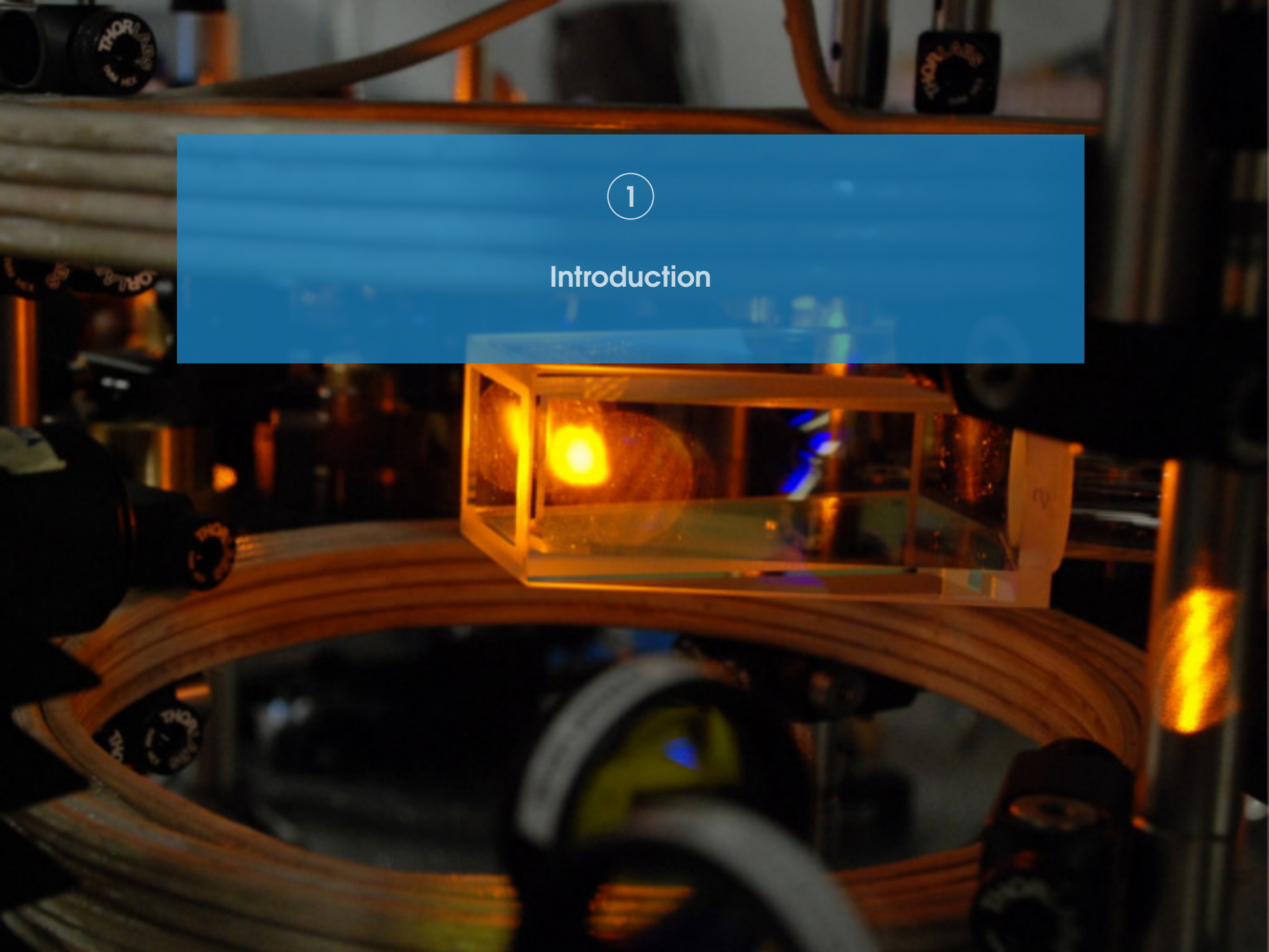


MACRO conference

Newcastle, September 14th, 2016



Our experimental setup to create sodium BECs



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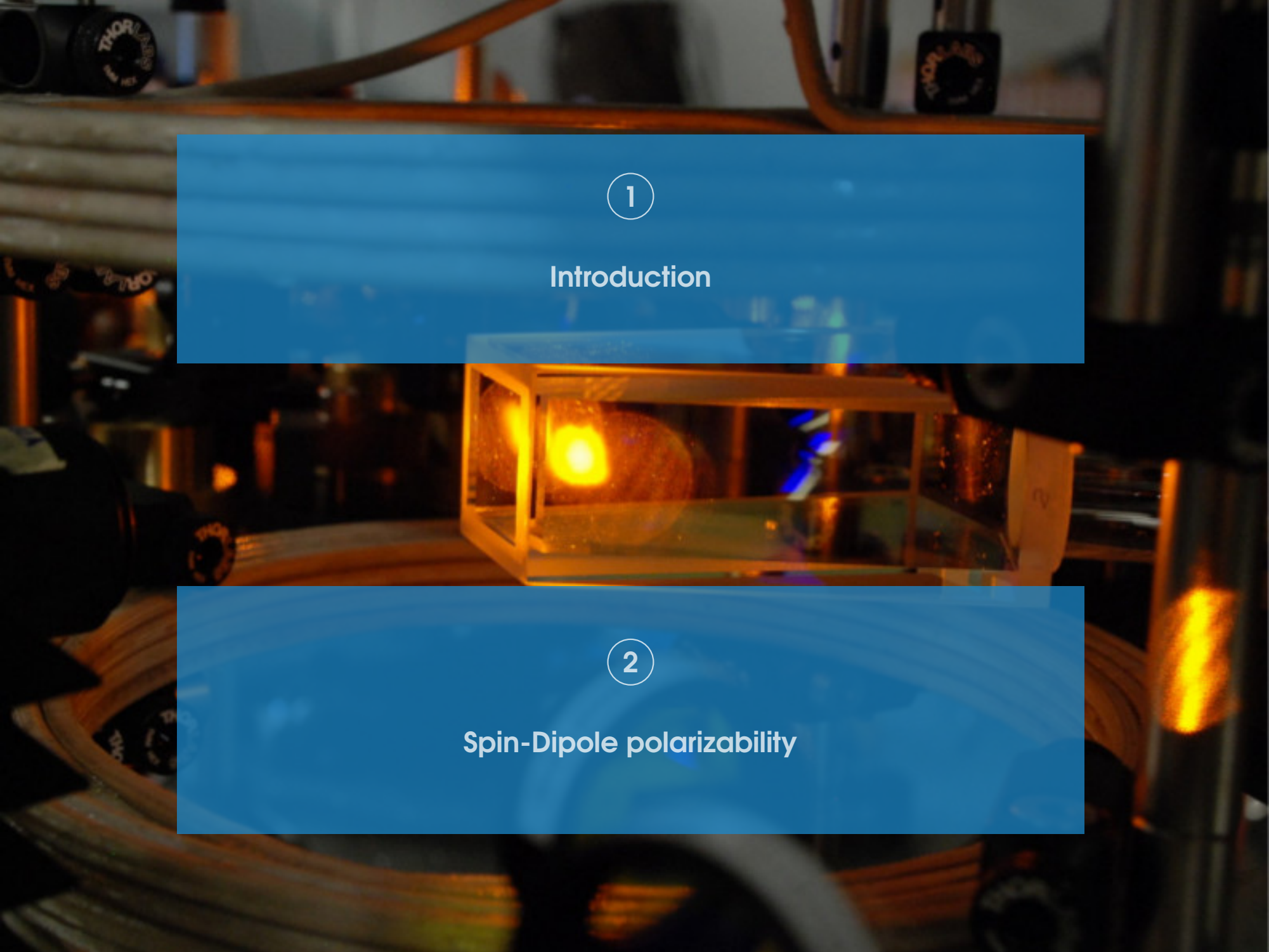
Introduction

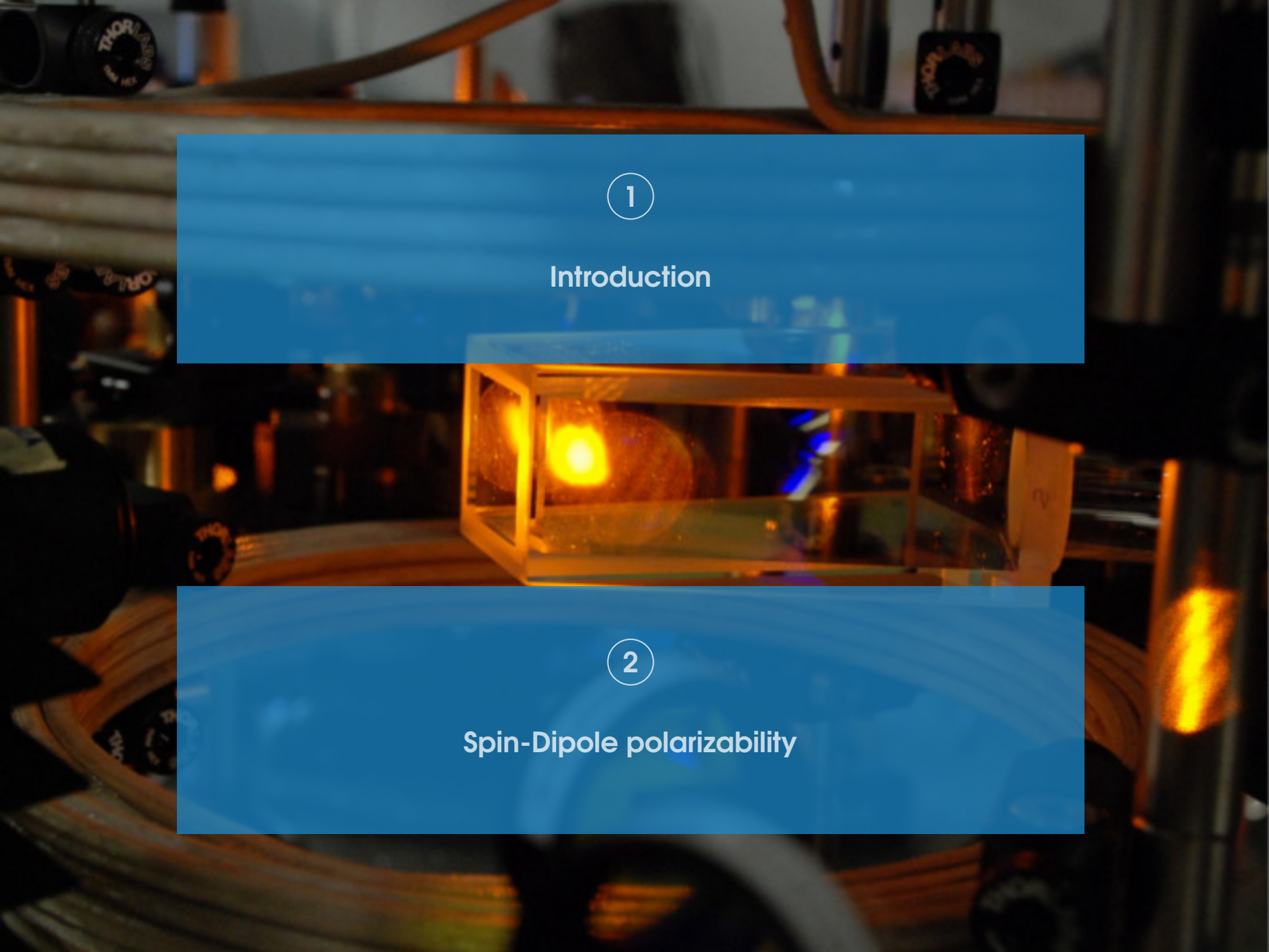


1

Introduction

2

Spin-Dipole polarizability

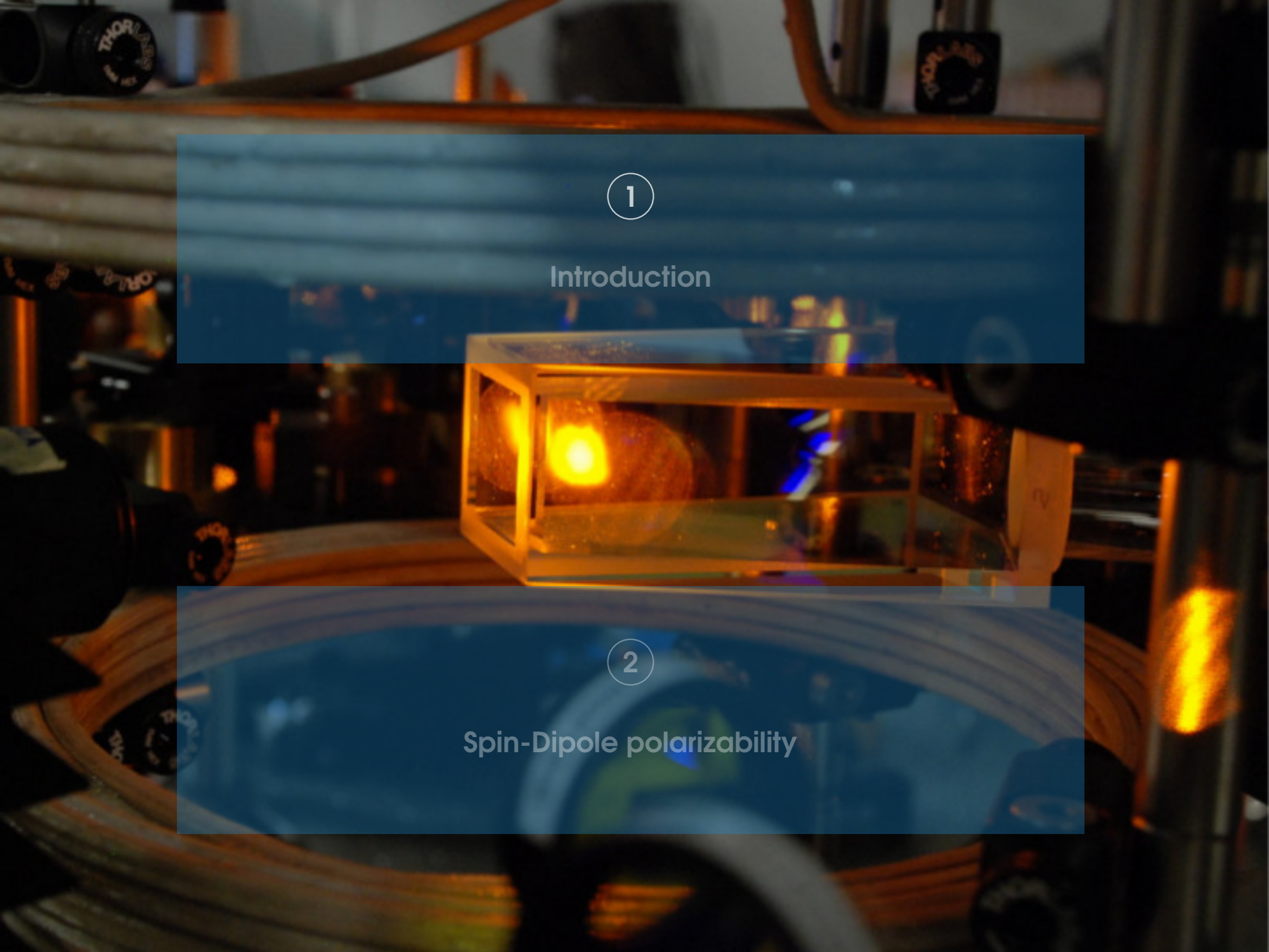


1

Introduction

2

Spin-Dipole polarizability



1

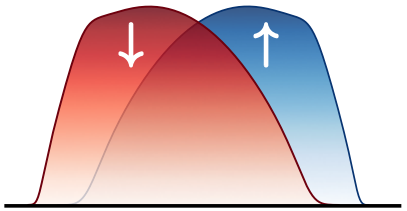
Introduction

2

Spin-Dipole polarizability

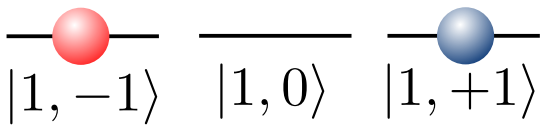
Introduction: Bose-Bose miscible mixture without buoyancy

- 2-component BEC: 2 Zeeman levels $|\uparrow\rangle, |\downarrow\rangle$
- Caracterized by scattering lengths:
  - Intracomponent: $a_{\uparrow\uparrow}, a_{\downarrow\downarrow}$
  - Intercomponent: $a_{\uparrow\downarrow}$
- Important property: miscibility if $a_{\uparrow\downarrow} < \sqrt{a_{\uparrow\uparrow} a_{\downarrow\downarrow}}$



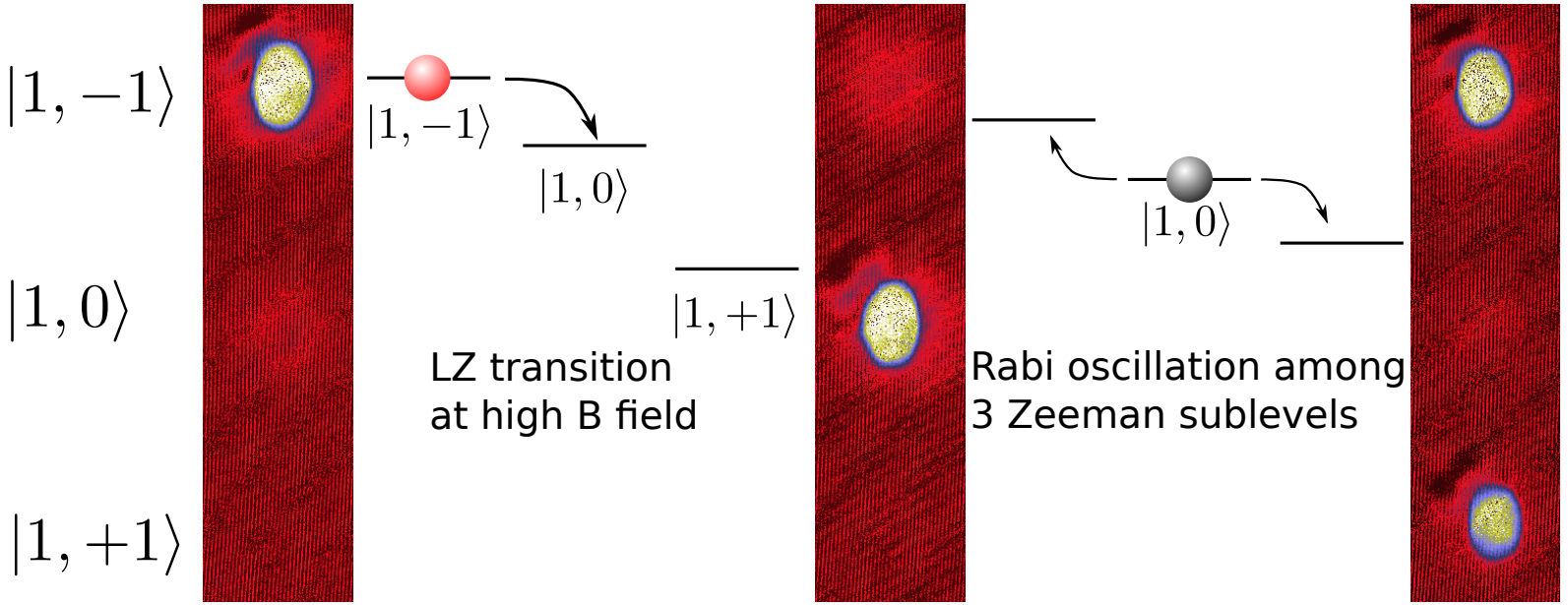
- Even when miscible: buoyancy problem in harmonic trap when $a_{\uparrow\uparrow} \neq a_{\downarrow\downarrow}$
- It prevents the study of the static and dynamic response in harmonic trap

- Our system: $|3^2S_{1/2}, F = 1, m_F = \pm 1\rangle$ states of sodium



- Advantages
  - Miscible
  - Without buoyancy $a_{\uparrow\uparrow} = a_{\downarrow\downarrow} \equiv a$
  - Close to the miscible/immiscible phase transition $(a - a_{\uparrow\downarrow})/a = 0.07 \ll 1$
- Goals
  - Study the linear and dynamic response
  - Observe that these properties are drastically modified close to the phase transition despite the weakly interacting nature of the gas

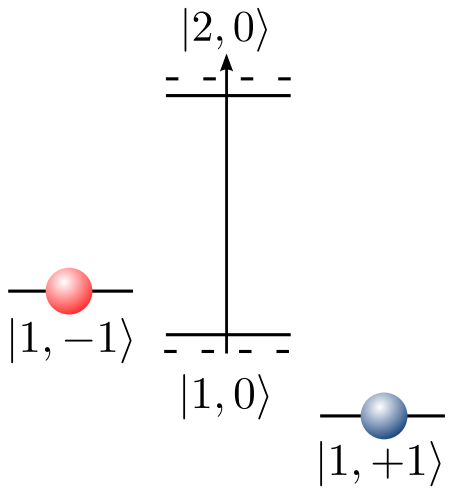
Spinor preparation



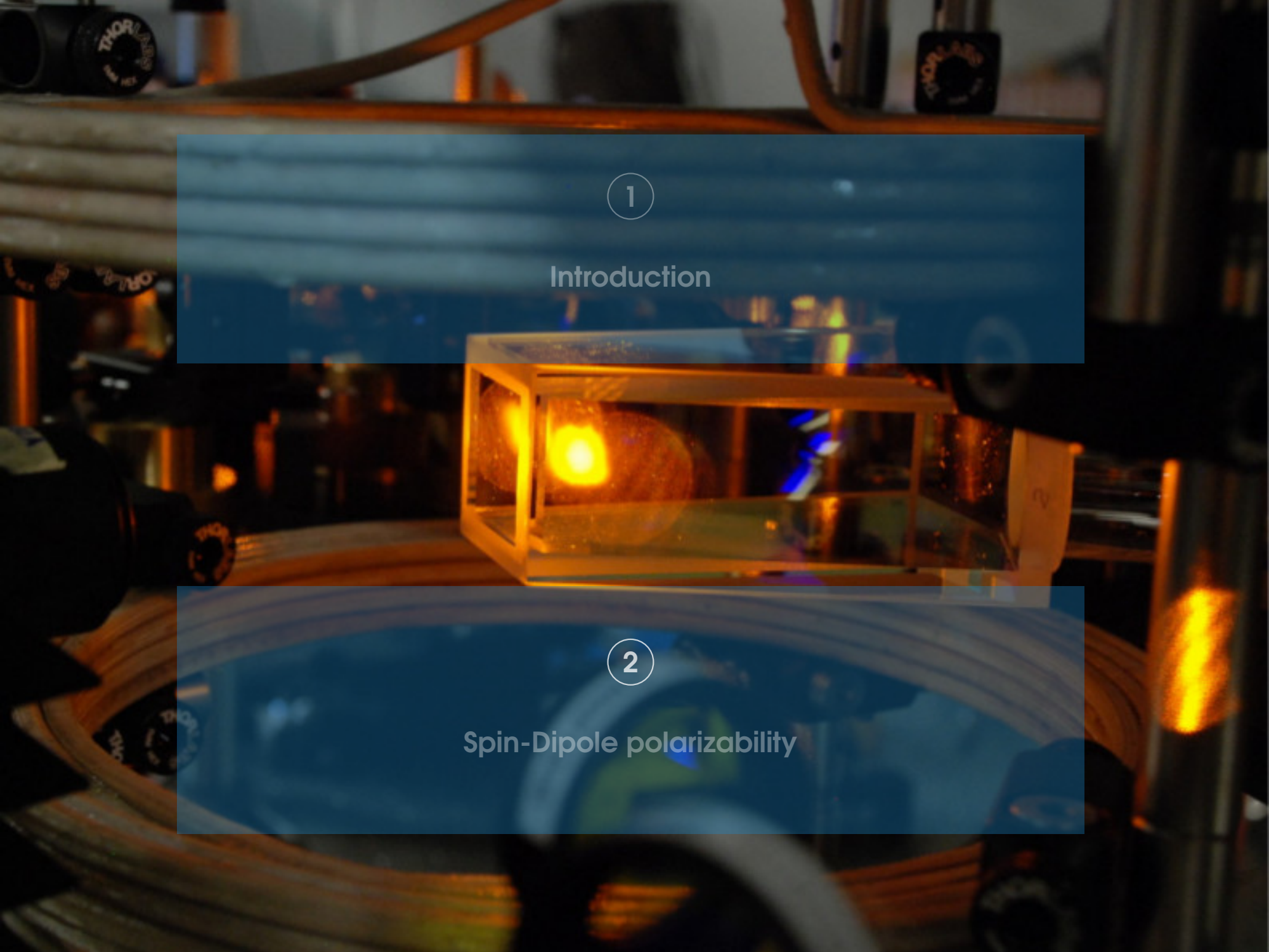
Goal: static and dynamic response of the system close to miscible/immiscible transition

Parameters:

$$N_\uparrow = N_\downarrow \simeq 10^6$$
$$[\omega_x, \omega_y, \omega_z]/2\pi = [47.7, 207.2, 156.8]\ \text{Hz}$$
$$a_{\uparrow\uparrow} = a_{\downarrow\downarrow} = 54.54(20)a_0$$
$$a_{\uparrow\downarrow} = 50.78(40)a_0$$



Stabilization using
MW dressing



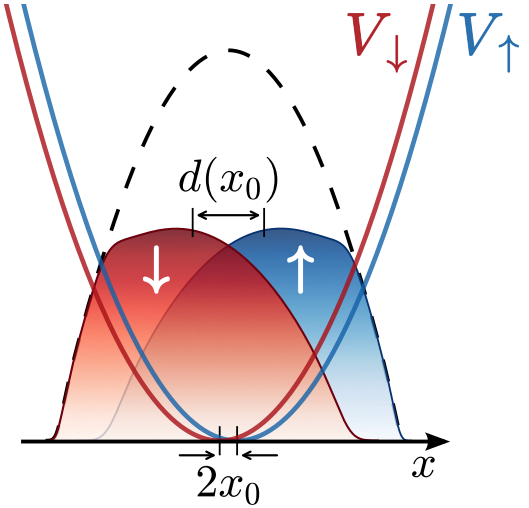
1

Introduction

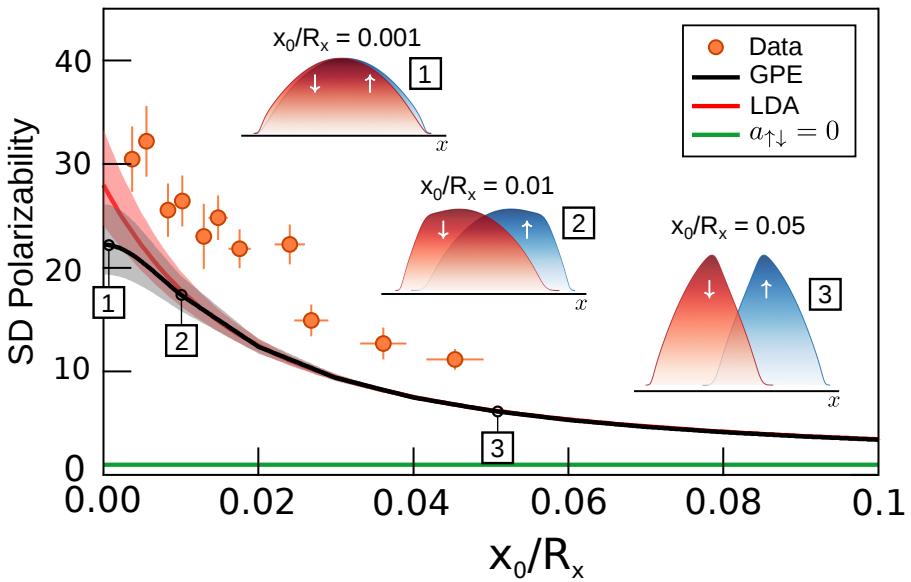
2

Spin-Dipole polarizability

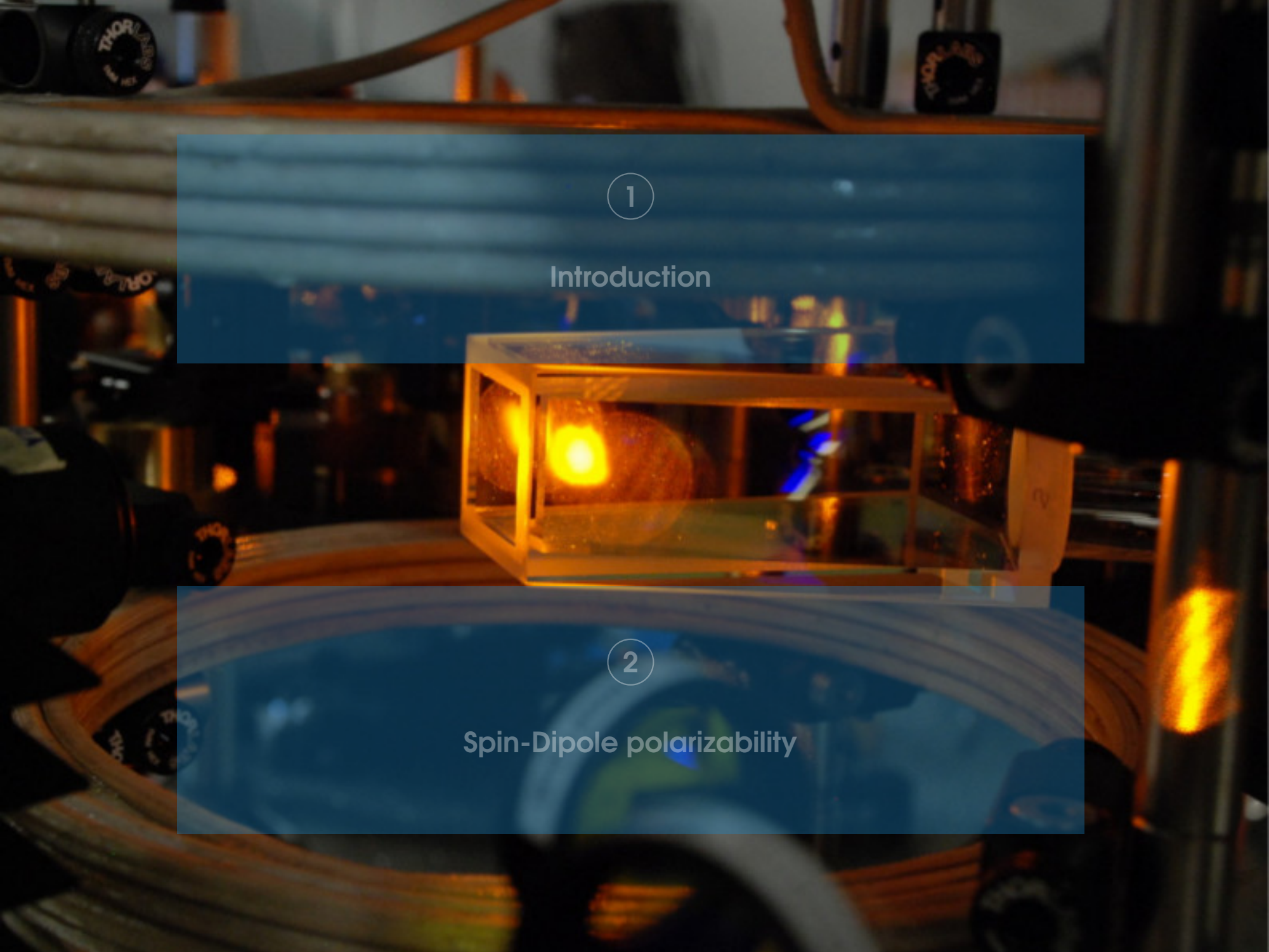
Spin-Dipole Polarizability: static measurement



Define SD polarizability: $\mathcal{P}(x_0) \equiv \frac{d(x_0)}{2x_0}$



LDA calculation: $\mathcal{P}(x_0 \to 0) = \frac{a + a_{\uparrow\downarrow}}{a - a_{\uparrow\downarrow}}$



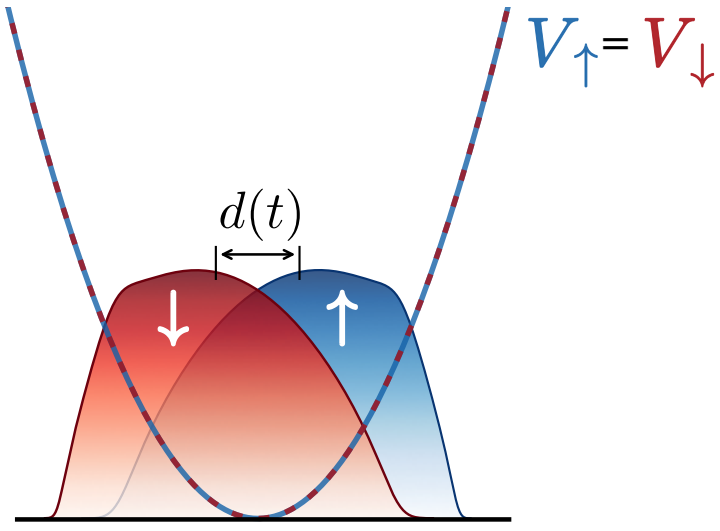
1

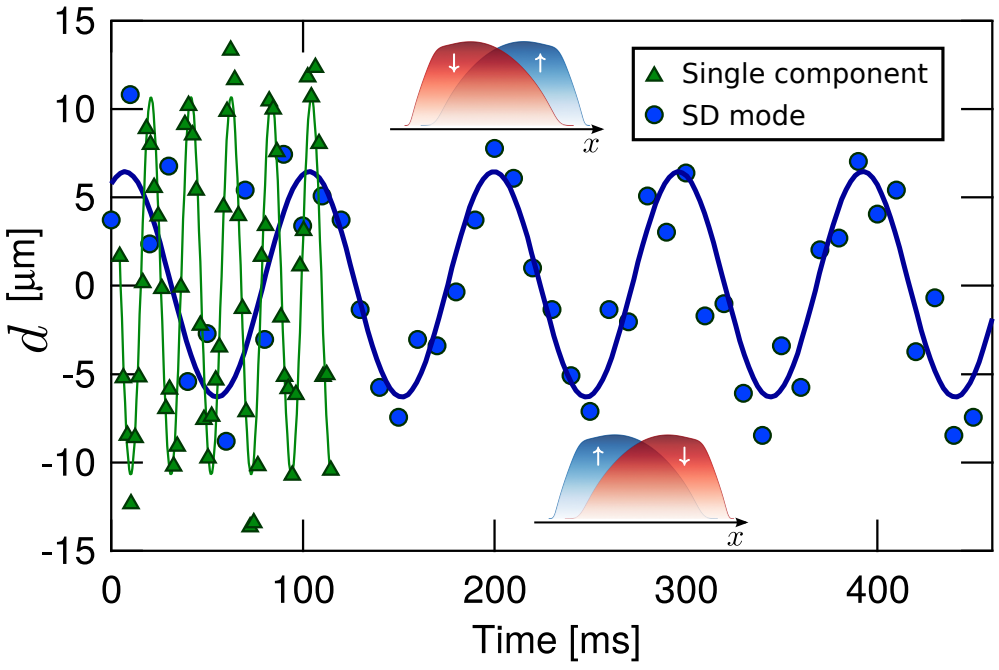
Introduction

2

Spin-Dipole polarizability

Spin-Dipole Oscillation: dynamic measurement



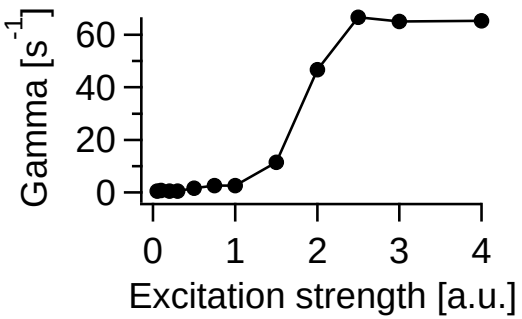


- We measure $\omega_{\mathrm{SD}}/\omega_x = 0.218(2)$
  - LDA $\omega_{\mathrm{SD}} = 0.189(15)\omega_x$
  - GPE $\omega_{\mathrm{SD}} = 0.213(17)\omega_x$
- Sum rule approach links polarizability $\mathcal{P}$ and SD mode frequency ω_{SD}:

$$\omega_{\mathrm{SD}} = \frac{1}{\sqrt{\mathcal{P}}}\omega_x$$

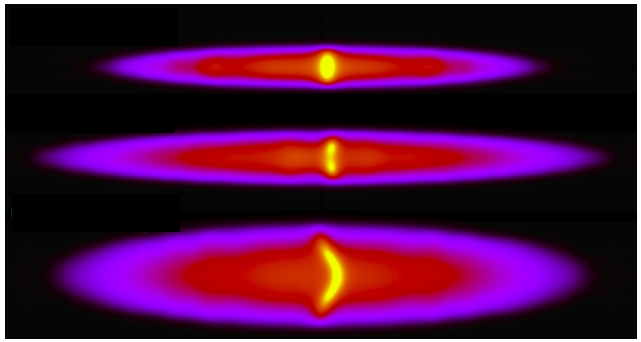
Outlook

Dynamical instability



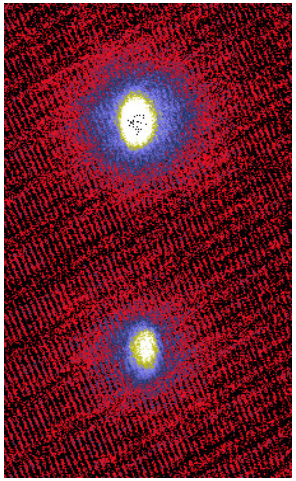
M. Abad et al., EPJD (2015)

Magnetic soliton



C. Qu et al., PRL (2016)

Finite temperature (four fluid model)

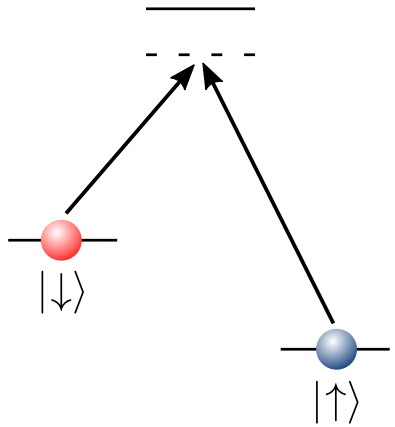


J. Armaitis et al., PRA (2015)

K. L. Lee et al., PRA (2016)

Coherent coupling between spin components

Many references and ideas...



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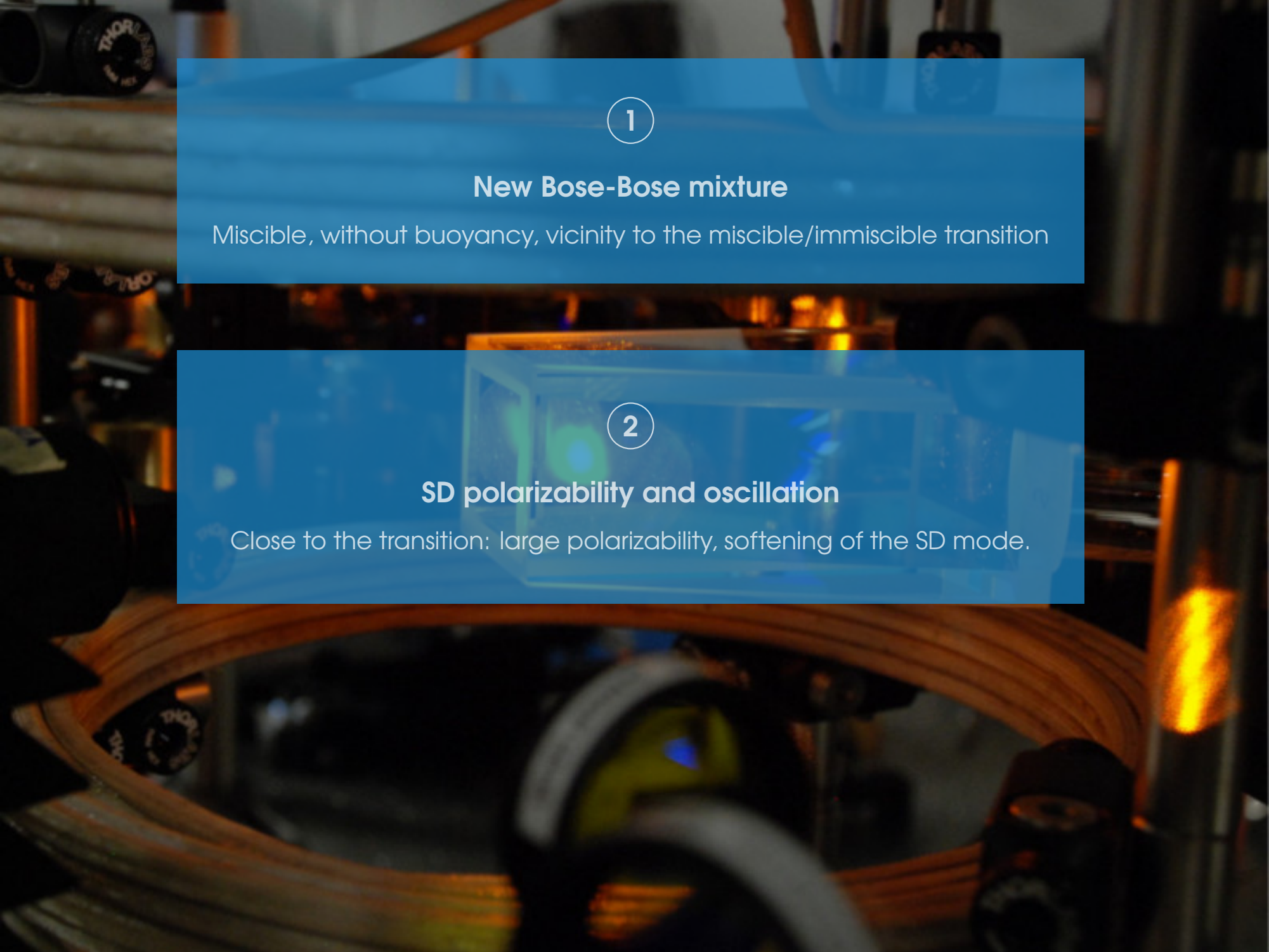
New Bose-Bose mixture

Miscible, without buoyancy, vicinity to the miscible/immiscible transition



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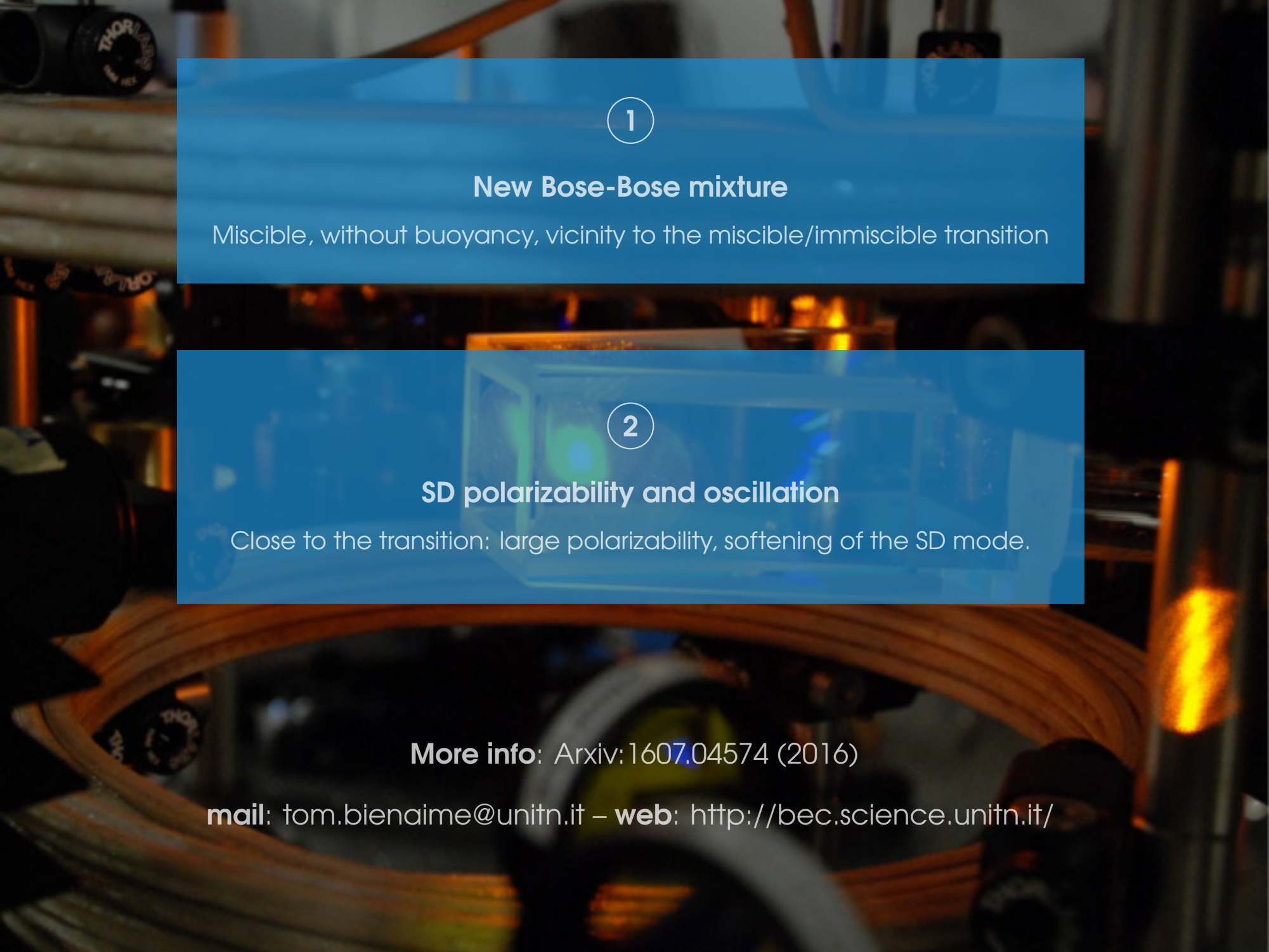
SD polarizability and oscillation

Close to the transition: large polarizability, softening of the SD mode.



1

New Bose-Bose mixture

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SD polarizability and oscillation

Close to the transition: large polarizability, softening of the SD mode.

More info: Arxiv:1607.04574 (2016)

mail: tom.bienaime@unitn.it – **web**: http://bec.science.unitn.it/

Acknowledgments

- BEC experiment @ Trento

  T. Bienaimé
  E. Fava
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  G. Ferrari

- Theoretical study @ Trento

  C. Qu
  S. Stringari

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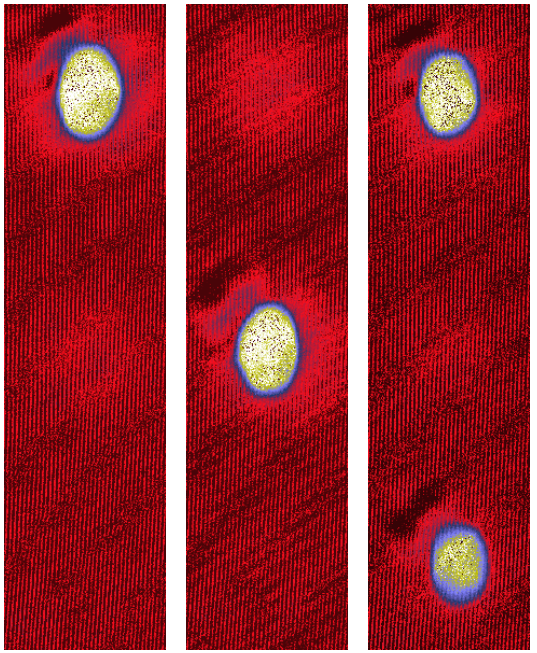

Thank you for your attention !