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Observation of Mie scattering from a superconducting micro-particle

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Abstract

A spherical superconducting micro-particle generated by laser ablation in superfluid helium is trapped in a quadrupole magnetic field. Utilizing the property that the particle is isolated in space, observation of the Mie scattering from this particle has been carried out. Analyzing the results, information on the optical properties of superconducting micro-particle and their shapes at helium temperature have been deduced.

1. Introduction

A superconducting micro-particle generated by laser ablation of its base material in superfluid helium and be trapped in a quadrupole magnetic field [1]. This trap is based on the Meissner effect and is robust when surrounding helium temperature is below the superconducting transition temperature of the micro-particle. The micro-particle floating in a space is a suitable target for the optical observation because it is free from stray light although the solid angle for the observation is somehow restricted due to the helium cryostat. We have carried out the observation of the Mie scattering from the trapped particle. Analyzing the results, we have obtained the information on the optical properties of superconducting micro-particles and their shapes at helium temperature.

2. Experiments and discussion

The scheme of the generation of superconducting particles and spatial capture has been described in the previous paper [1]. A flat surface of indium metal as a base metal (indium in this experiment) placed in superfluid helium is irradiated with a focused beam of a pulsed Nd:YAG laser with a pulse width of 5 ns and a pulse energy of a few mJ to generate a micro-particle. This micro-particle is cooled down below its superconducting critical temperature by the contact with the surrounding liquid helium at 1.5 K, and then is trapped in a quadrupole magnetic field composed of a pair of neodymium magnets placed in front of the base metal as shown in Fig. 1. In case that several particles are trapped, their number is reduced by heating them above their critical temperature by the irradiation of a high power cw laser. Thus, an experiment using one particle can be performed. The size of the trapped particle can be observed by using a scanning electron microscope (SEM) after the cryogenic experiment is carried out. For that purpose the copper plate can be placed under the trapped particle and capture the falling particle by gradually raising the temperature of surrounding liquid helium. The images of the trapped indium particles are almost spherical and the size of them is around sub- to several μm in diameter.

As shown in Fig. 2, by irradiating with a low power cw laser, scattered light from the trapped particle is collected by a CMOS camera through a macro zoom lens, which are place on a rotating stage to adjust the scattering angle. The resolution of the scattering angle is reduced by placing a small aperture in front of the lens. In this way, we can measure the angle distribution of the scattered light. The experimental parameters are the laser wavelength and its polarization. In this paper, we use three laser wavelength λ of 450, 532 and 633 nm and its parallel polarization.

In comparison with the calculation using Mie theory for a spherical particle, radius r and extinction coefficient $\kappa(\lambda)$ of the superconducting indium particle at a

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temperature of 1.5 K can be deduced. Our discussion is focused on:

a) Optical properties of indium was discussed by Golovashkin et al [2]. Our data extend their data for the lower wavelength. Is there any indication for the superconductivity in the optical properties ?

b) The radius obtained by the analysis of the Mie scattering is considerably small compared with that measured by the SEM at the room temperature considering the known expansion rate.

We will discuss the present and future of this study in this talk.

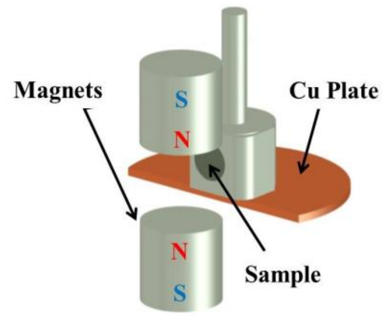

Fig. 1 Experimental set up for magnetic trap of superconducting micro-particle.

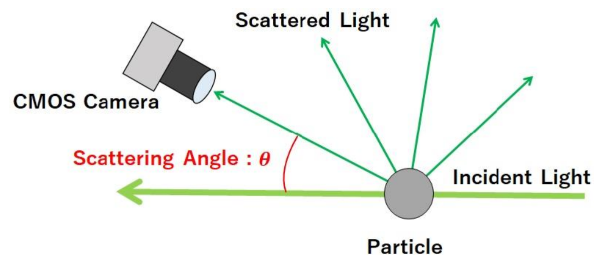

Fig. 2 Experimental set up for the Mie scattering from the micro-particle.

References

[1] Y. Takahashi et al., Appl. Phys. Express, 10, 022701 (2017).

[2] A. I. Golovashkin et al., Sov. Phys. JETP, 24, 1093 (1967).