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Imaging Circular Dichroism of Single Nanoparticles Using Photothermal Microscopy

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Chiral nanoparticles are those nanostructures whose mirror image cannot be superimposed onto each other. Enantiomers of a chiral nanoparticle interact differently with left- and right-circularly polarized light. Circular dichroism (CD) is the differential absorption of left- and right-circularly polarized light. Circular birefringence (CB) or optical rotatory dispersion (ORD) is the rotation of the polarization direction of the linearly polarized light through a chiral medium. CD and CB are respectively related to the imaginary and real part of the dielectric function. Standard detection of CD of single nanoparticles is based on extinction or scattering and thus cannot measure a true CD signal. To detect a true CD signal of a single nanoobject, an absorption-based method is needed.

Photothermal microscopy [1] enables detection of absorption signals of very tiny nanoobjects down to 1 nm. Photothermal microscopy presents two major advantages for the detection of the CD of single nanoobjects: (i) a high degree of polarization control of circularly polarized light by using low-NA pump illumination and (ii) a high spatial resolution using high-NA illumination of the probe. To eliminate leakage of linear dichroism (LD) into CD, a dual-modulation of polarization of the pump beam is applied [2]. An electro-optic modulator (EOM) and a photo-elastic modulator (PEM) are used to modulate the polarization at two different frequencies and the CD is measured at their sum frequency. This allows us to reject LD from the CD signal by more than a factor of 300 and to detect the CD signal of single nanoparticles with a g-factor as low as 3×10^{-4}.

This new development of photothermal circular dichroism (PT CD) microscopy is further upgraded to detect the magnetic circular dichroism (MCD) signal of single magnetic nanoparticles [3]. Photothermal magnetic circular dichroism (PT MCD) microscopy enables the detection of the magnetization of single 20-nm magnetite nanoparticles [4]. Measurement of full magnetization curves of single magnetic nanoparticles shows spatio-temporal heterogeneities and can be explained using a simple Stoner-Wohlfarth model. PT MCD microscopy is able to detect the magnetization of single nanoparticles down to few 10^4 Bohr magnetons.

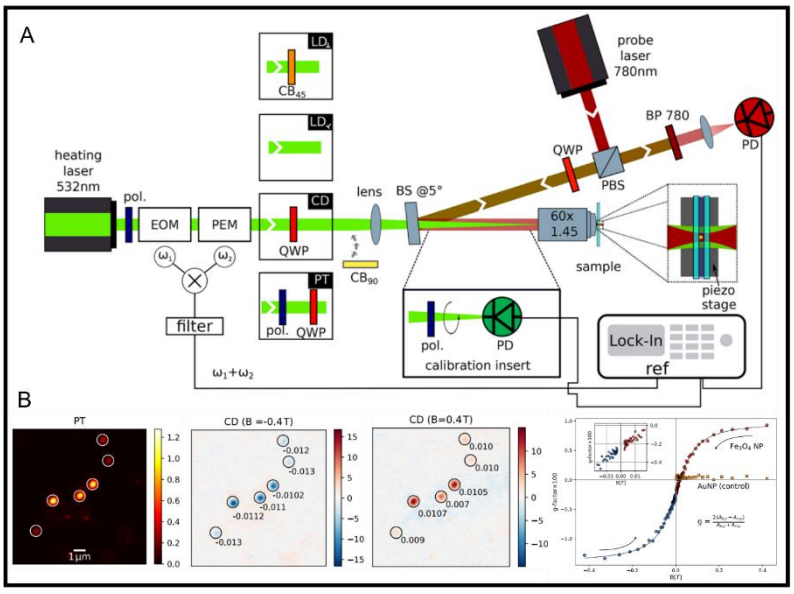

Fig. 1 (A) Schematic diagram of our dual-modulation photothermal circular dichroism (PT CD) microscope (ref. 2). (B) Photothermal and circular dichroism images of single magnetic nanoclusters at magnetic fields of −0.4 and 0.4 T, respectively, and the full magnetization curve of a single nanocluster (ref. 3).

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