APS Satellite Meeting at ICTS

Sensing magnetic environments using combination probes in an optical tweezer

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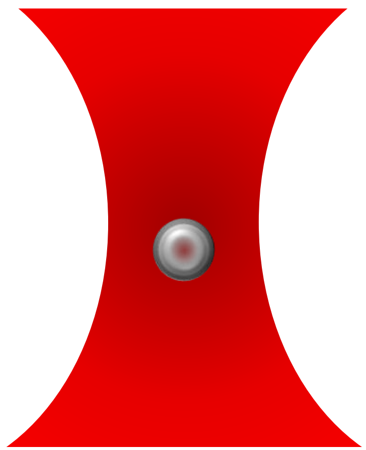
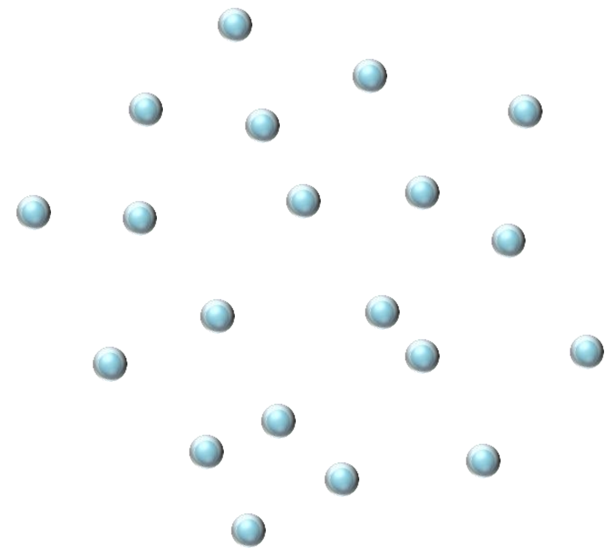
What is a combination probe?



Optically trapped 1µm silica bead



Ferrofluids: Aqueous, 100nm ø, Magnetite core, anion surface charge

Why is it not possible to trap nanoparticles in a conventional OT

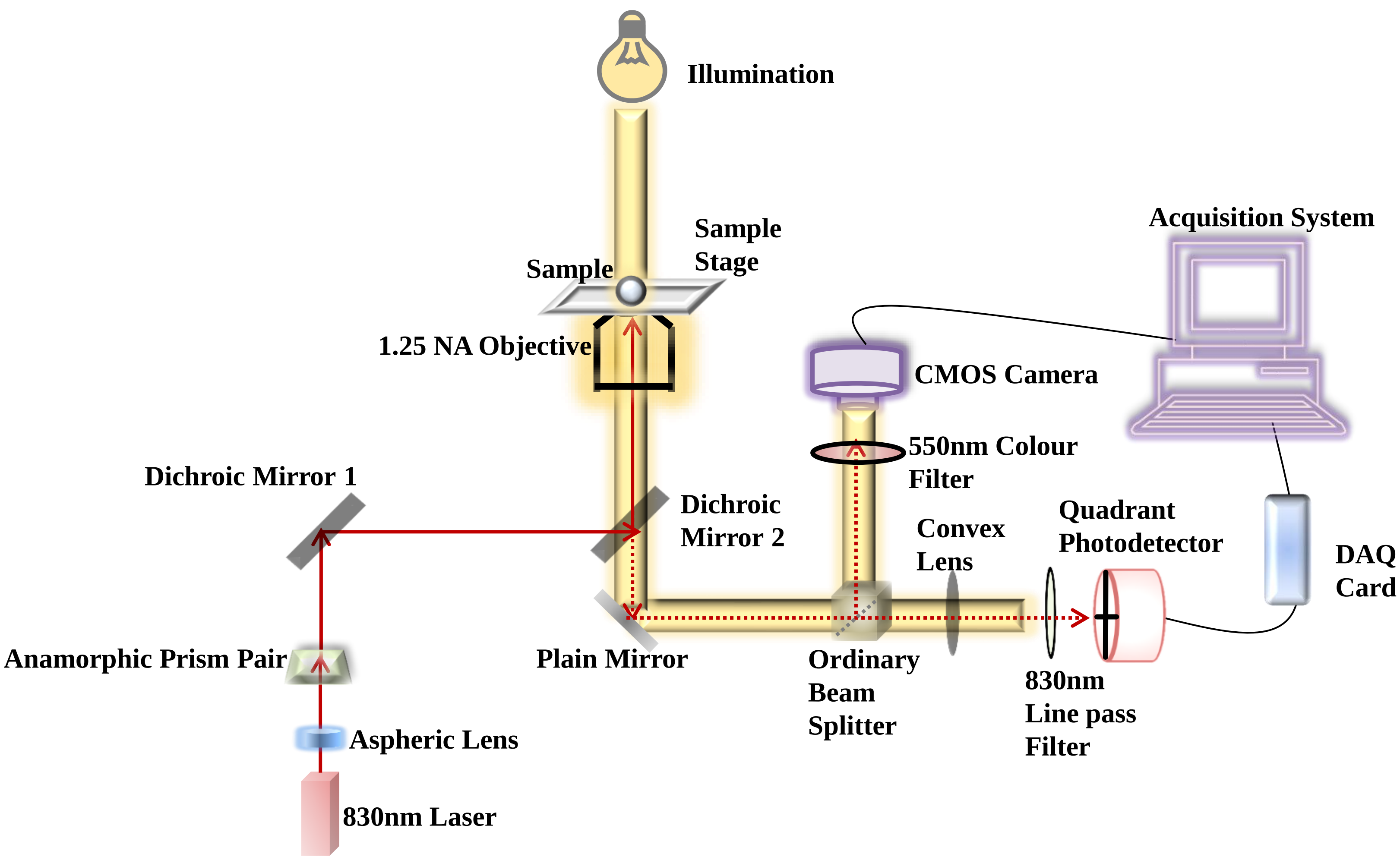
- *Optical trapping of nanoparticles depends critically on the material of the particle that influences the stability of trapping through the polarizability*

- *Techniques to trap nanoparticles optically thereby involve measures like design of nanoparticles with enhanced polarizability, use of plasmonic tweezers / near field optical trapping or the use of ultra-short laser pulses*

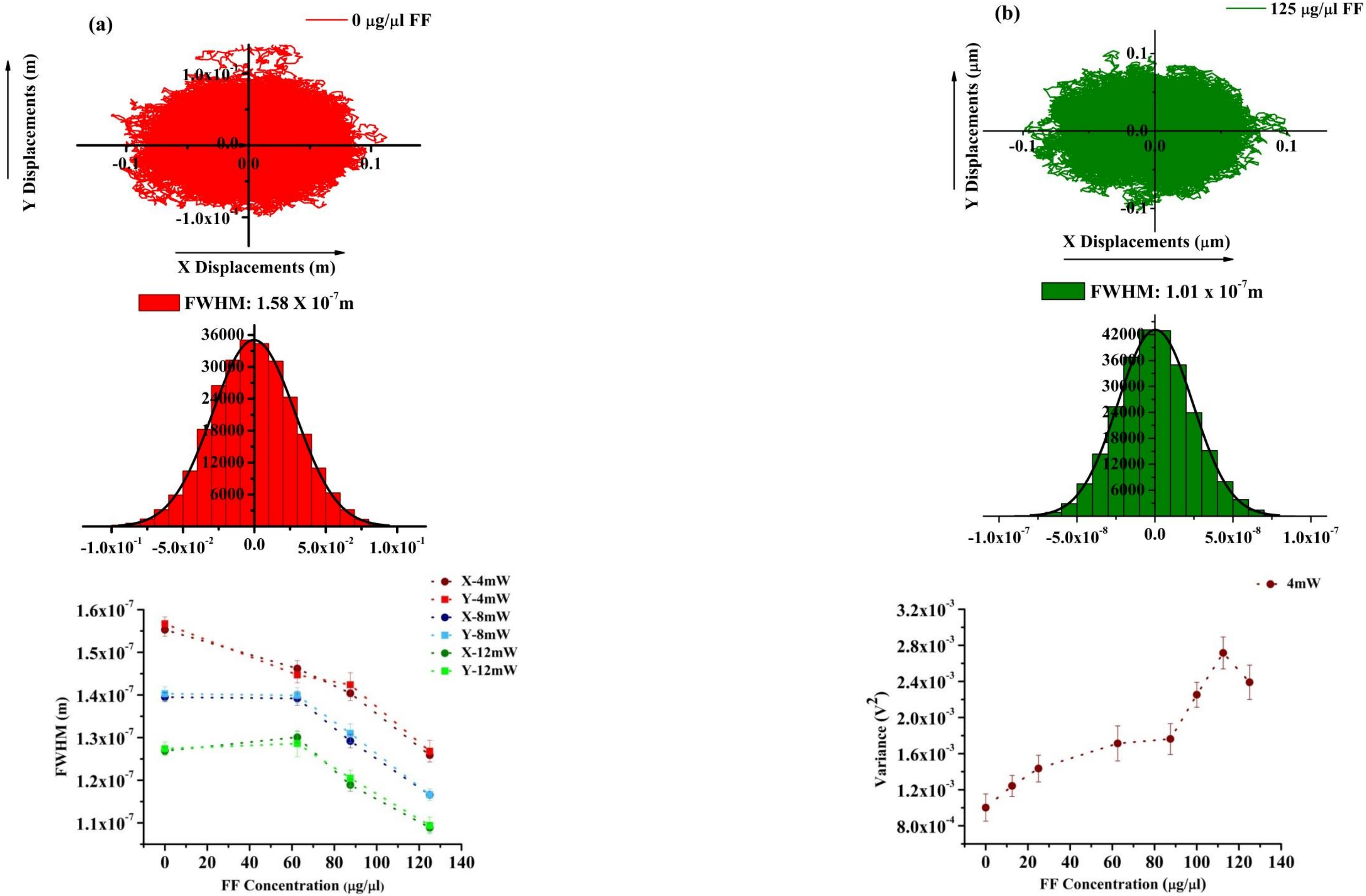
- *One can conclude that there is a strong possibility that conditions for stable trapping of nanoparticles are never satisfied in a conventional OT. Thus one may not observe the formation of clusters within the trap volume*

- *M. A .Zaman, P. Padhy and L. Hesselink, "Near-field optical trapping in a non-conservative force field", Sci. Rep, 9(649), 1-11 (2019)*
- *M. L. Juan, M. Righini and R. Quidant, "Plasmon nano-optical tweezers", Nat. Photonics, 5, 349-356 (2011)*
- *P. M. Bendix, L. Jauffred, K. Norregaard, and L. B. Oddershede, "Optical Trapping of Nanoparticles and Quantum Dot ", IEEE J. Sel. Top. Quant., 20(3), 2014*

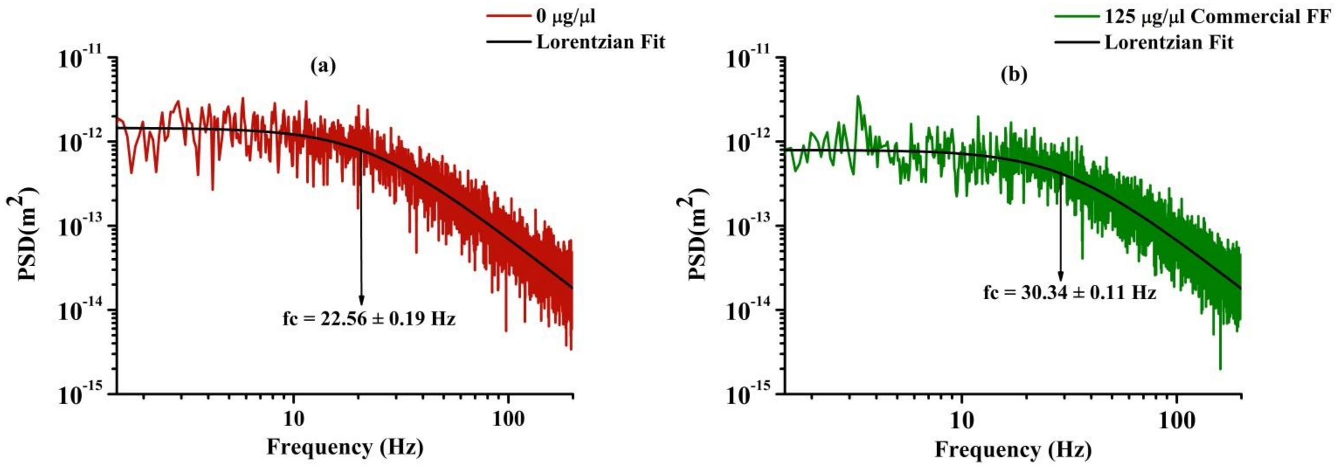
Schematic of the optical tweezer setup used

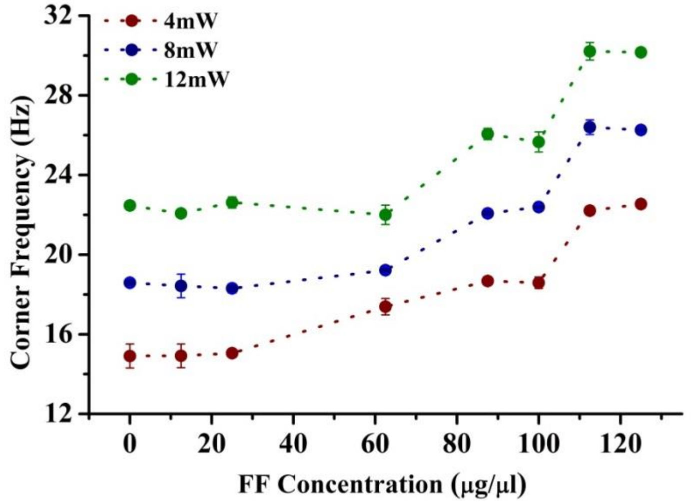


What happens when a non-magnetic probe is optically trapped when in a nanoparticle suspension

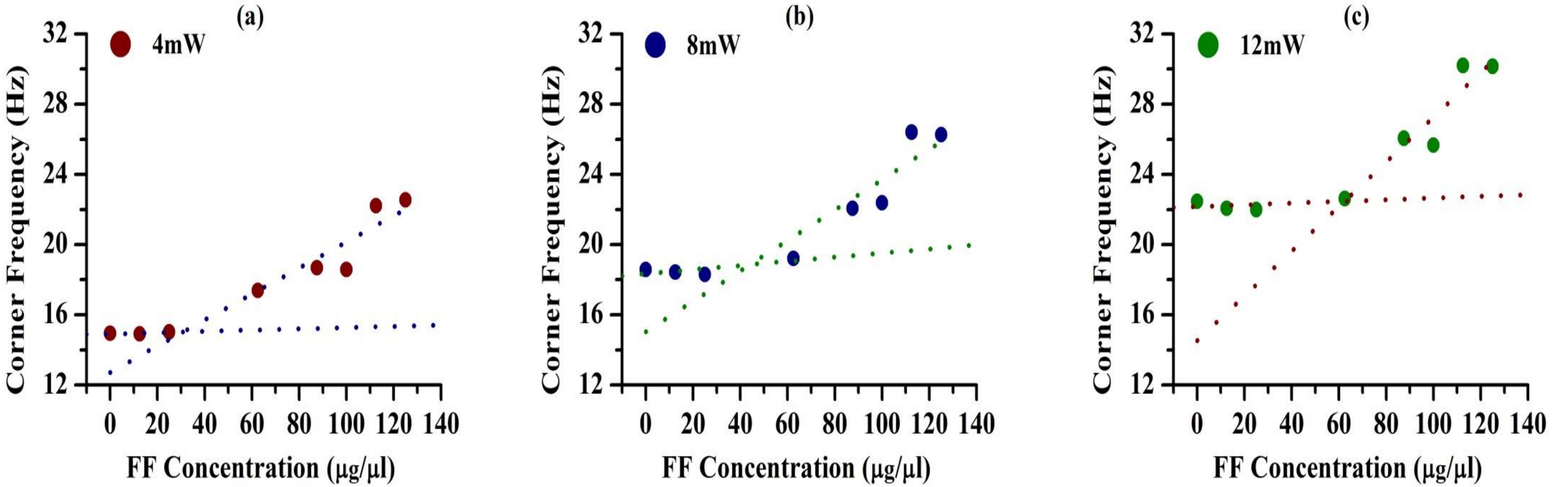


Analysis of power spectral density



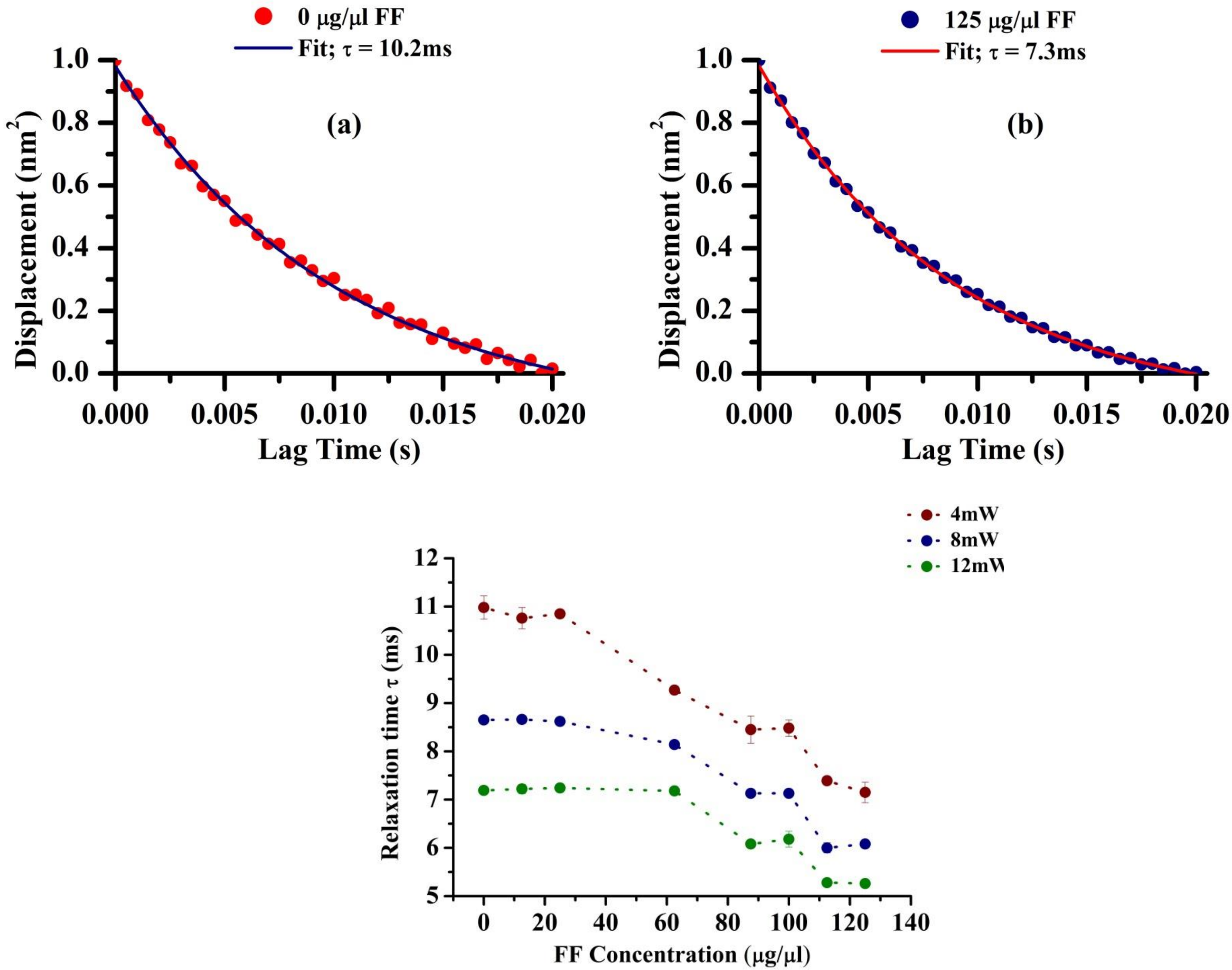


Estimation of threshold concentration

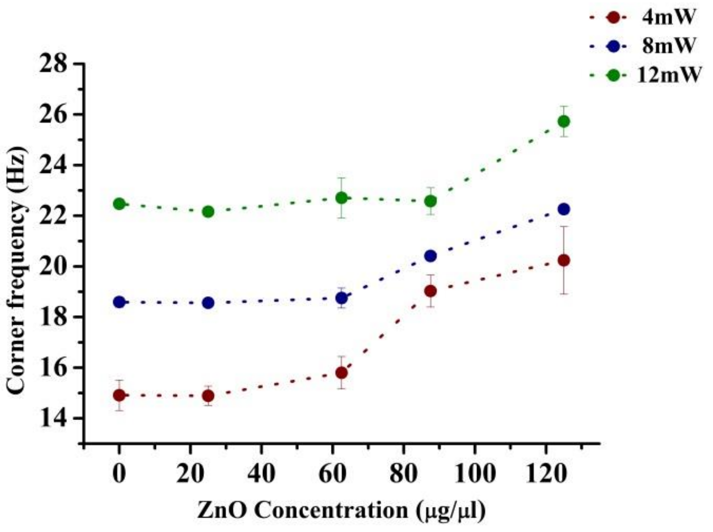


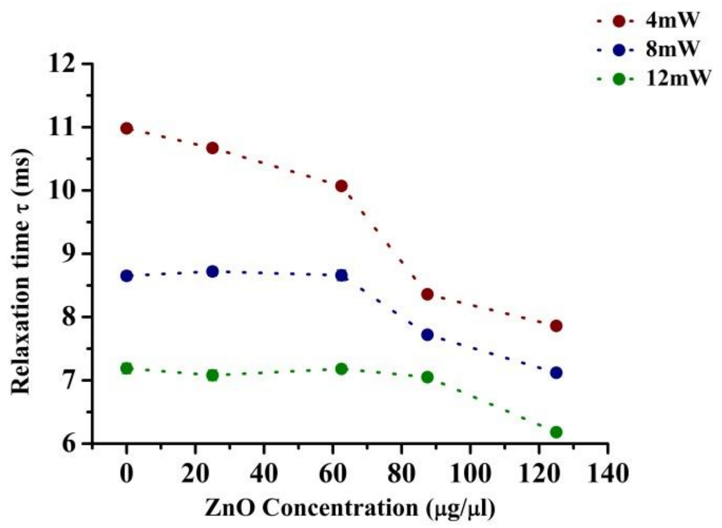
Power (mW)	Value of threshold FF concentration (μg/μl)
4	30.0
8	45.0
12	65.5

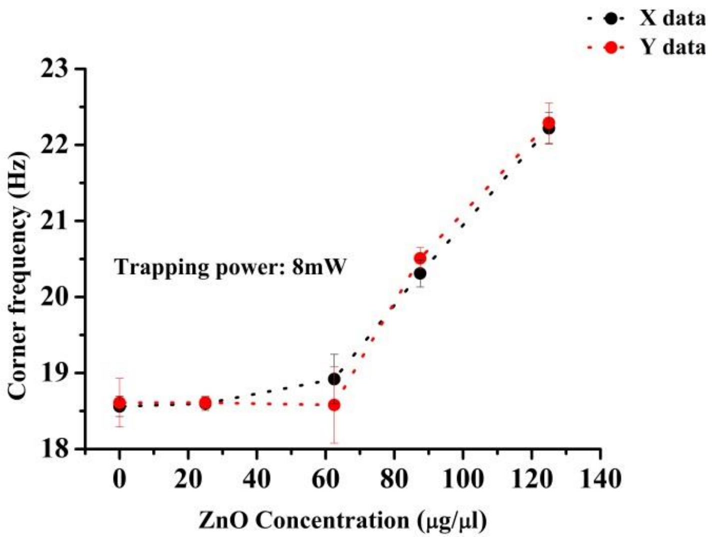
Autocorrelation function analysis

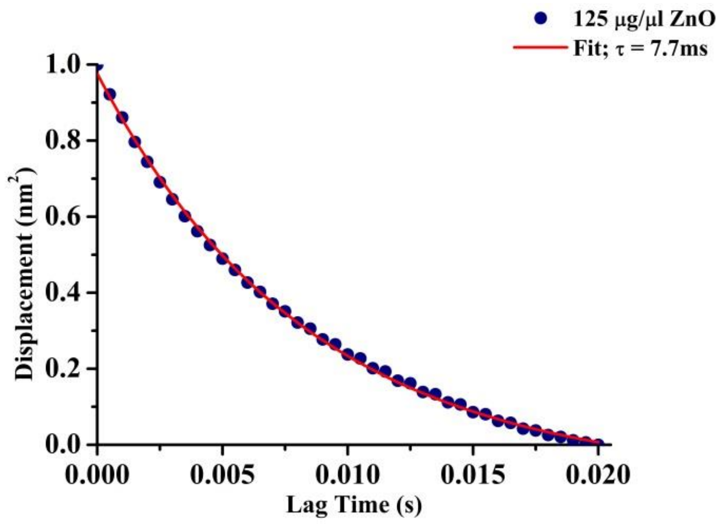


Commercial ZnO nanoparticles



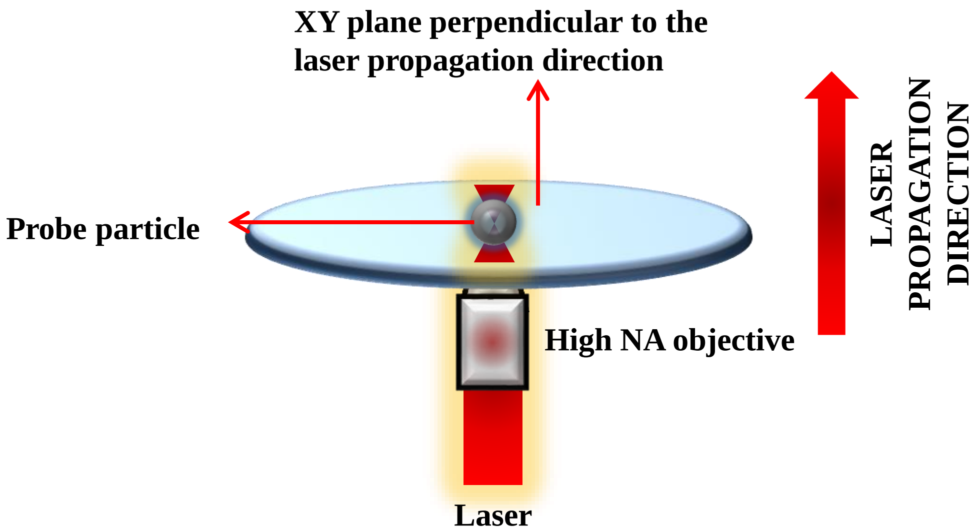


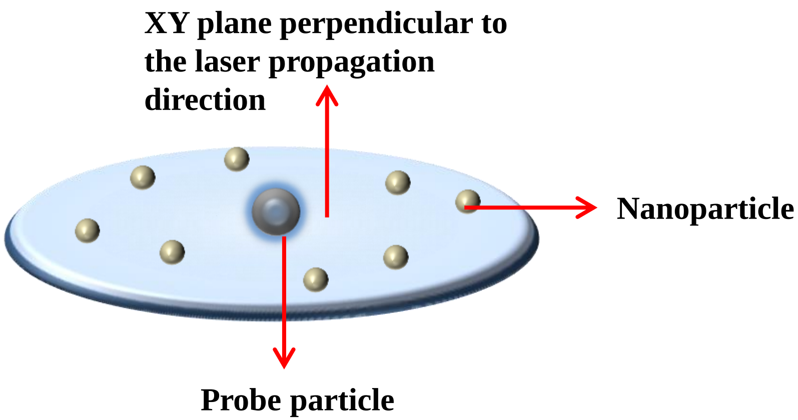


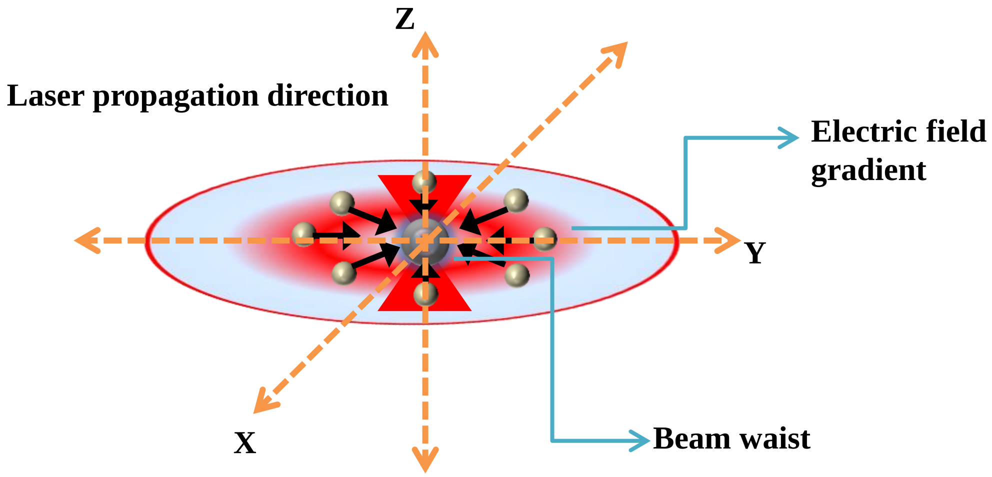


Aqueous, 40nm ø, uncoated (Sigma Aldrich)

What we think is happening here



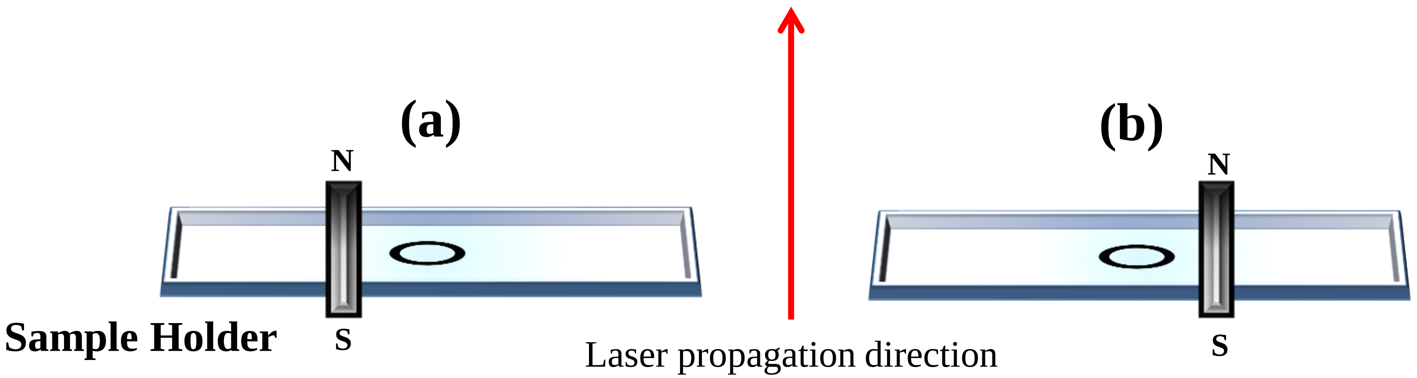


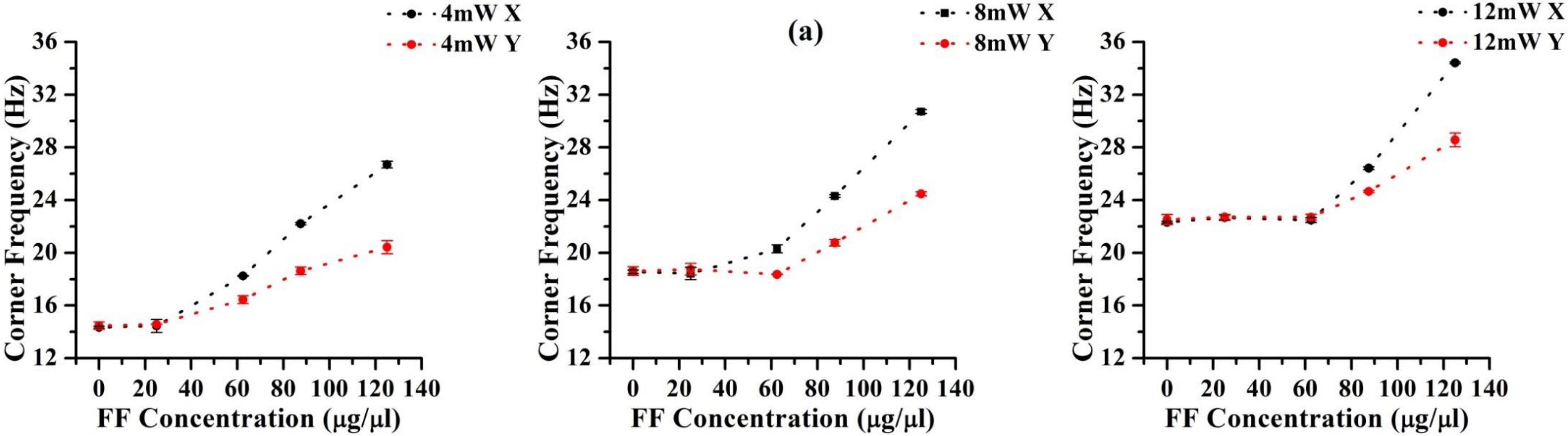


Shruthi Subhash Iyengar, Praveen Parthasarathi, Sharath Ananthamurthy, Sarbari Bhattacharya, "Trap stiffness modification of an optically trapped microsphere through directed motion of nanoparticles", Appl. Opt. 59(17), 5114-5123 (2020)

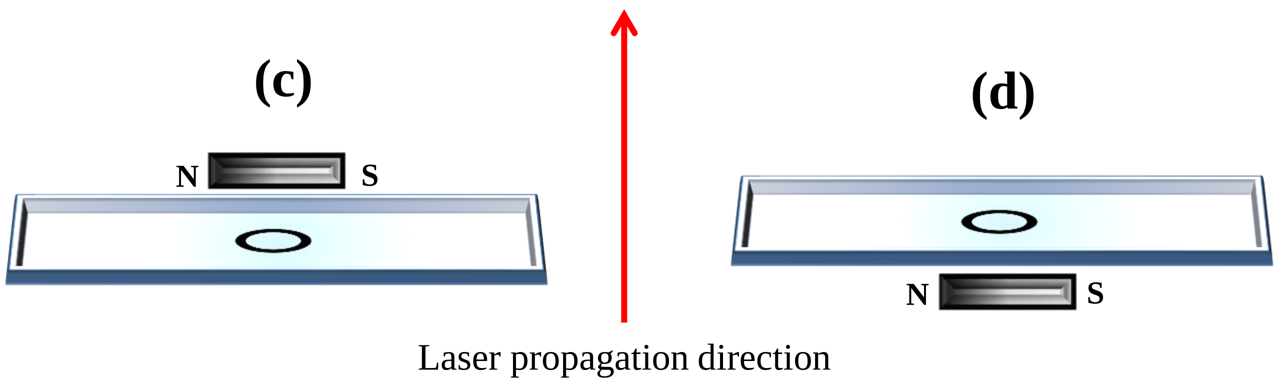
RESPONSE TO VARIOUS MAGNETIC ENVIRONMENTS

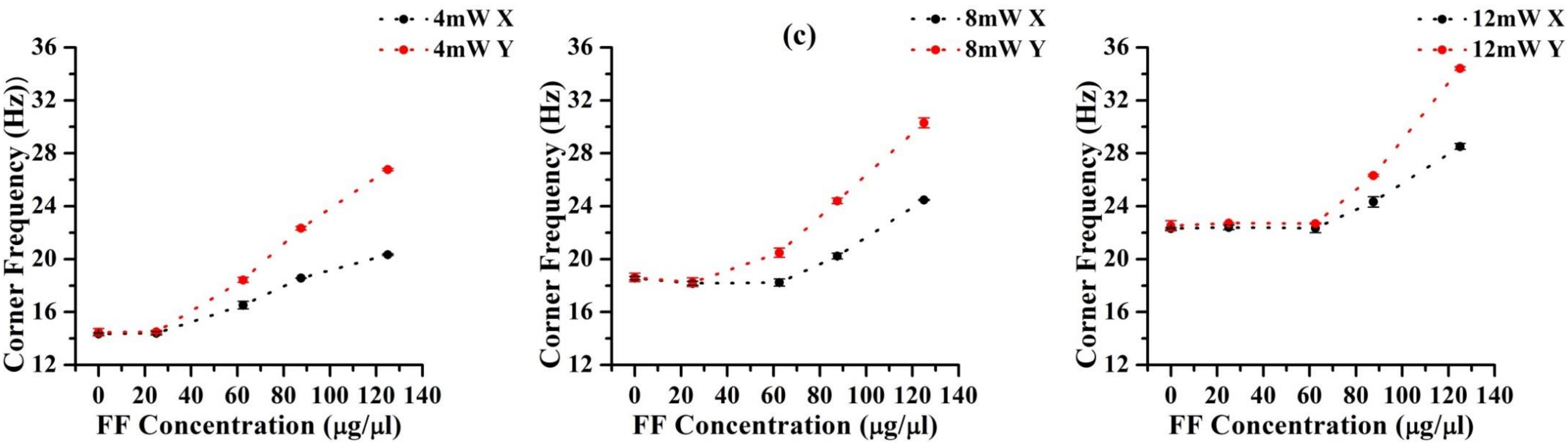
Single Magnet – left and right



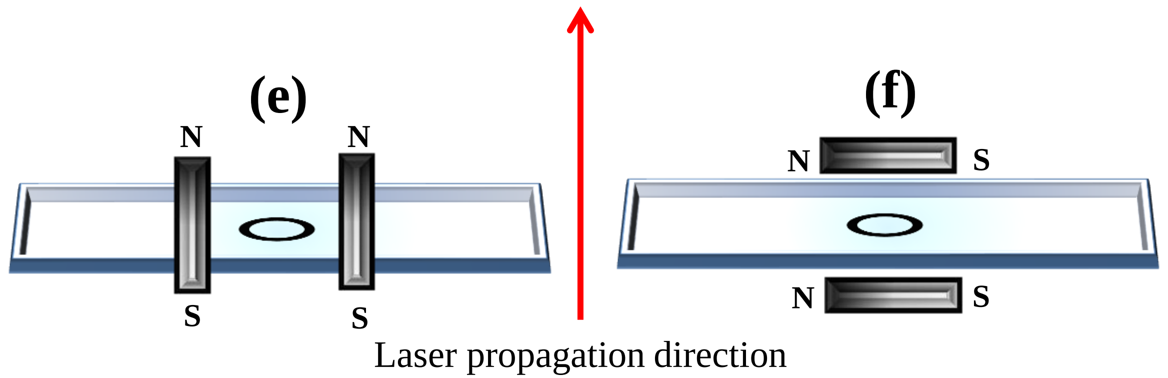


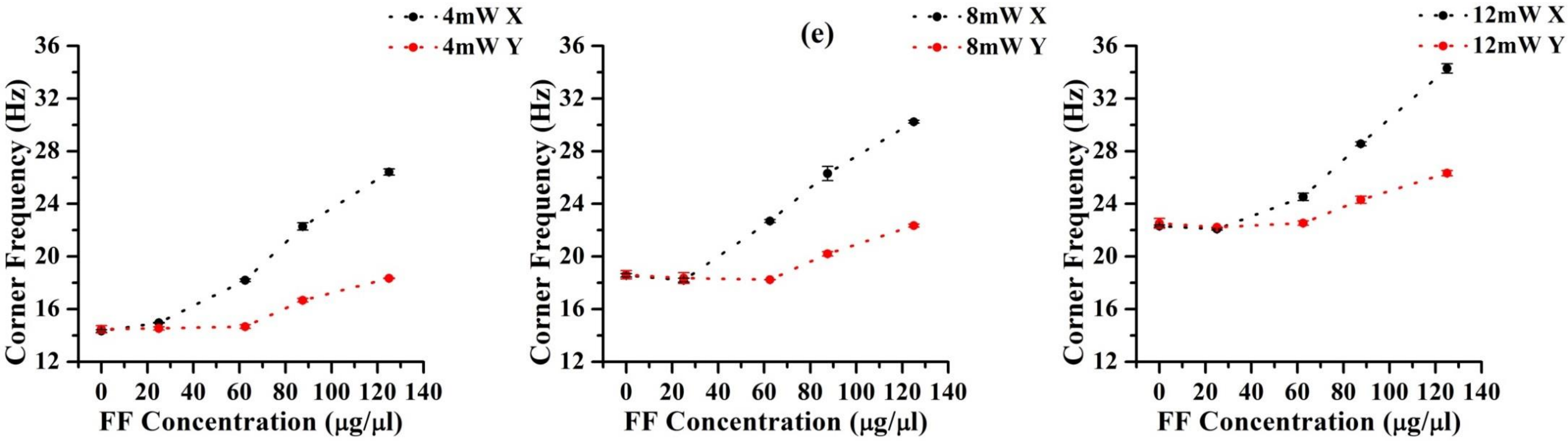
Single Magnet – top and bottom



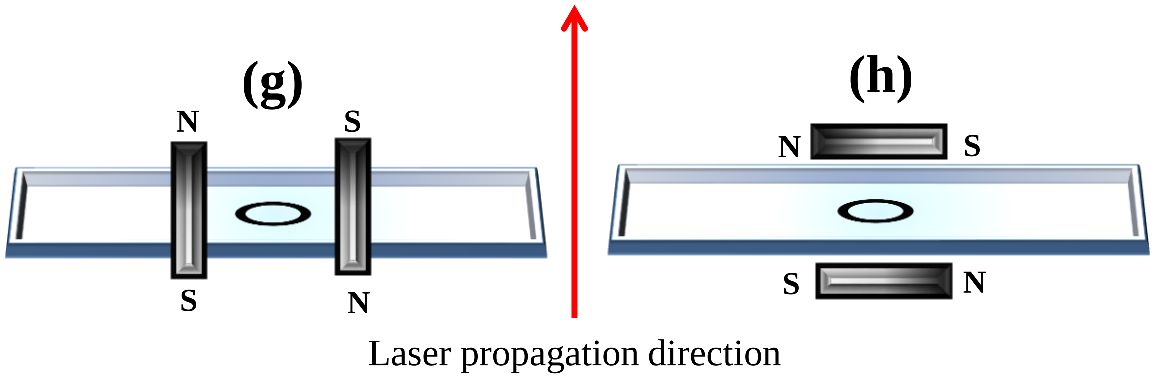


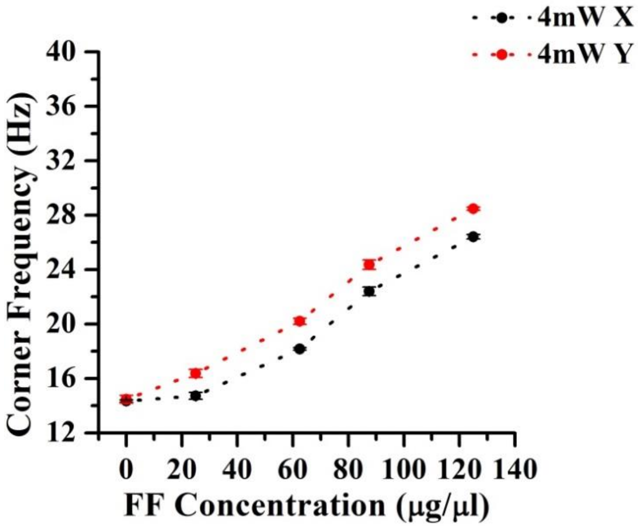
Double Magnets – Parallel configuration

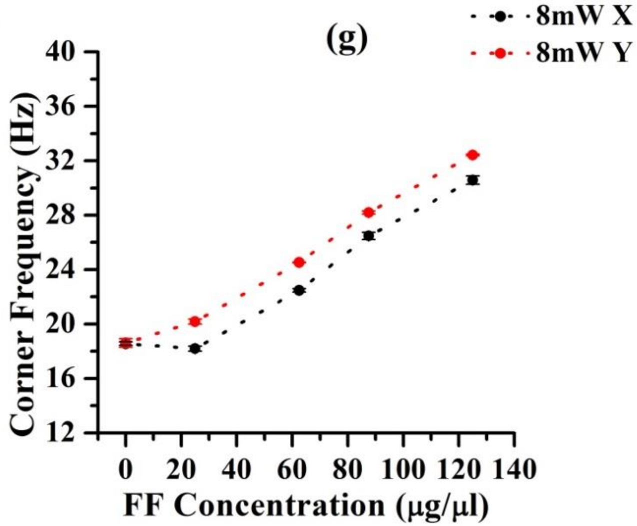


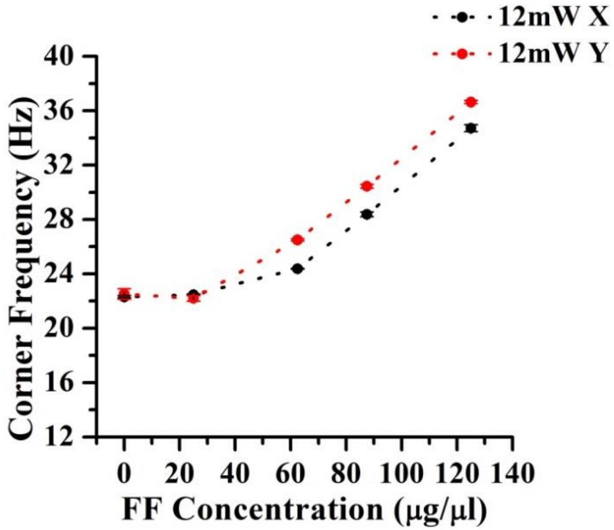


Double Magnets – Anti-Parallel configuration





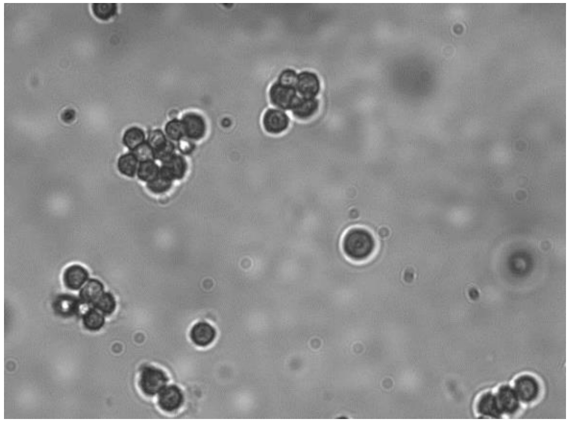




Magnetic beads in the presence of magnetic nanoparticles

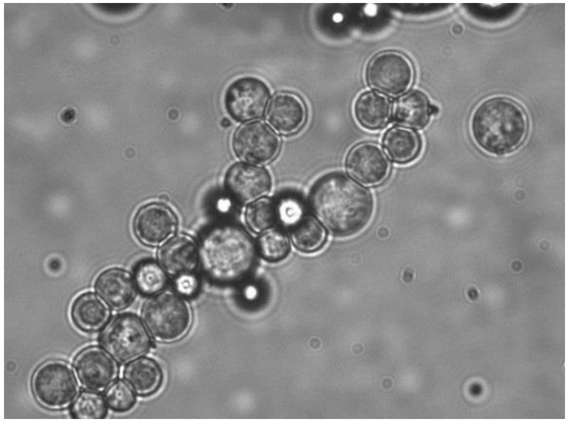
Ferromagnetic Beads (FMBs)

CrO_2 layer of nanoparticles on polystyrene matrix

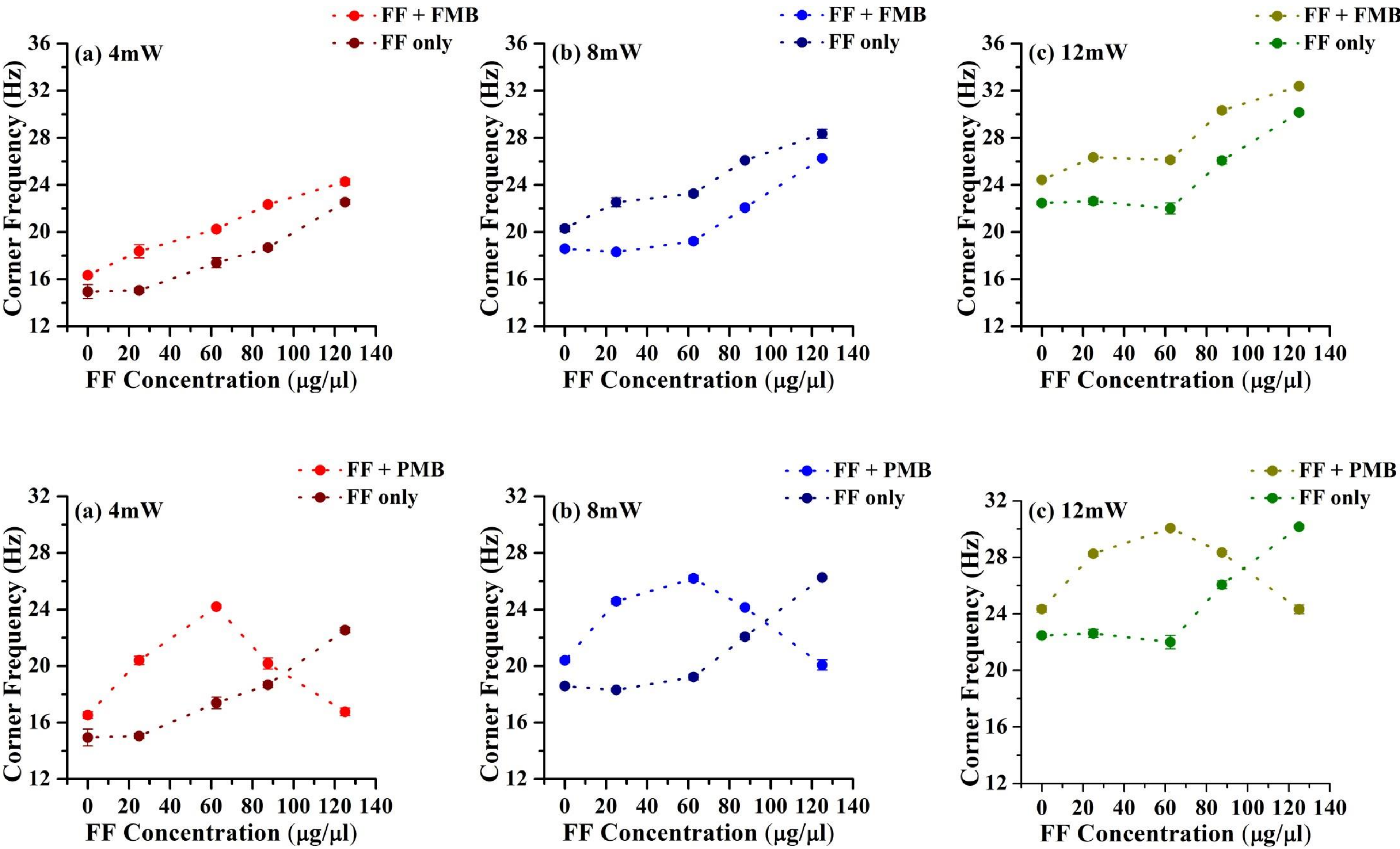


Polystyrene-composite Magnetic Beads (PMBs)

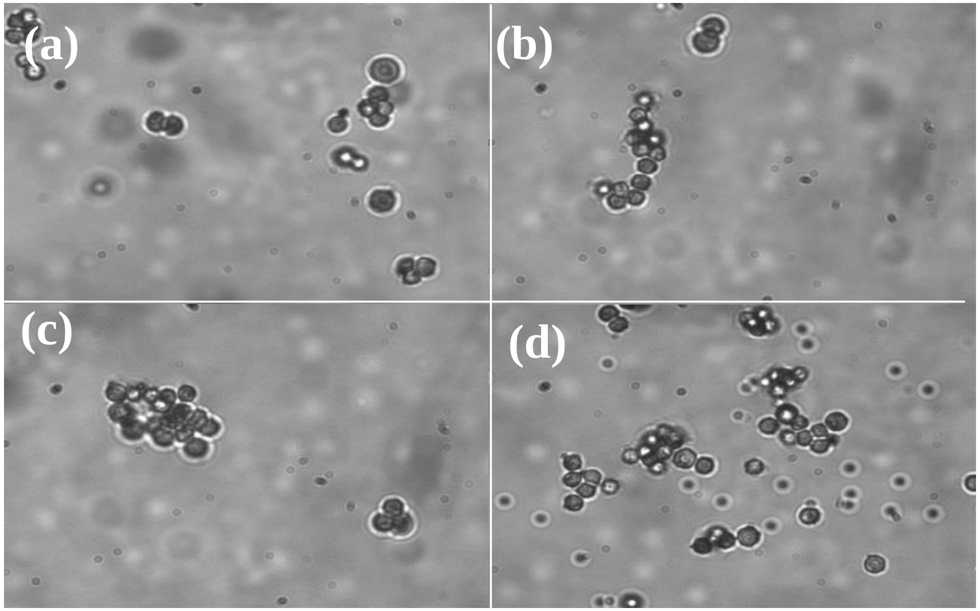
Fe_3O_4 layer of nanoparticles on polystyrene matrix, additional polystyrene coating,

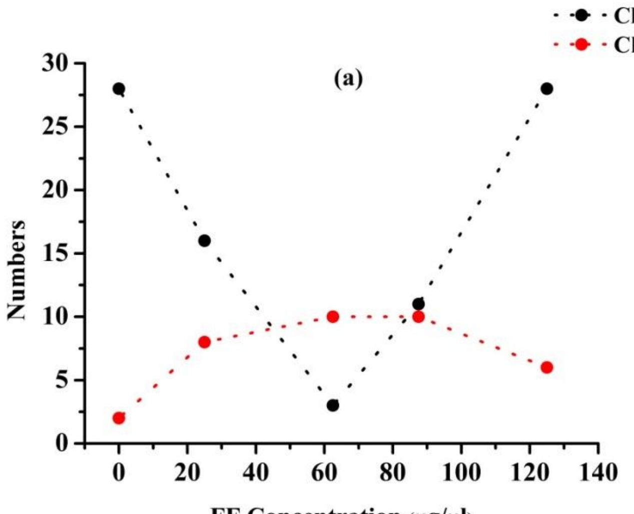


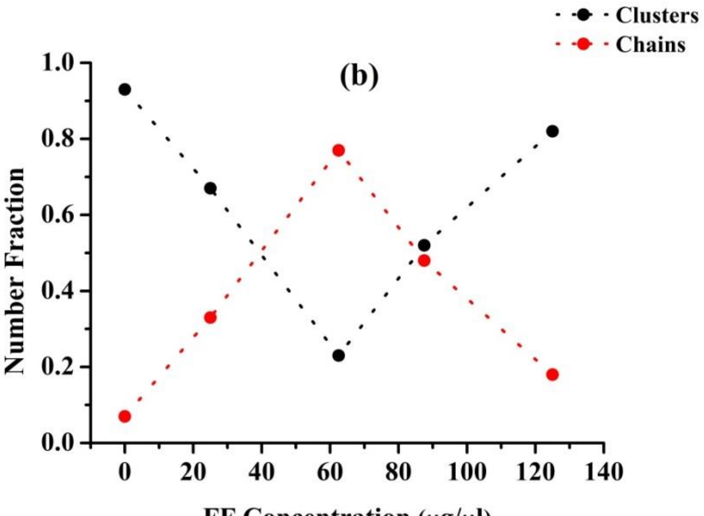
Fluctuation behaviour of a trapped probe with different ferrofluid concentrations in the presence of FMBs and PMBs



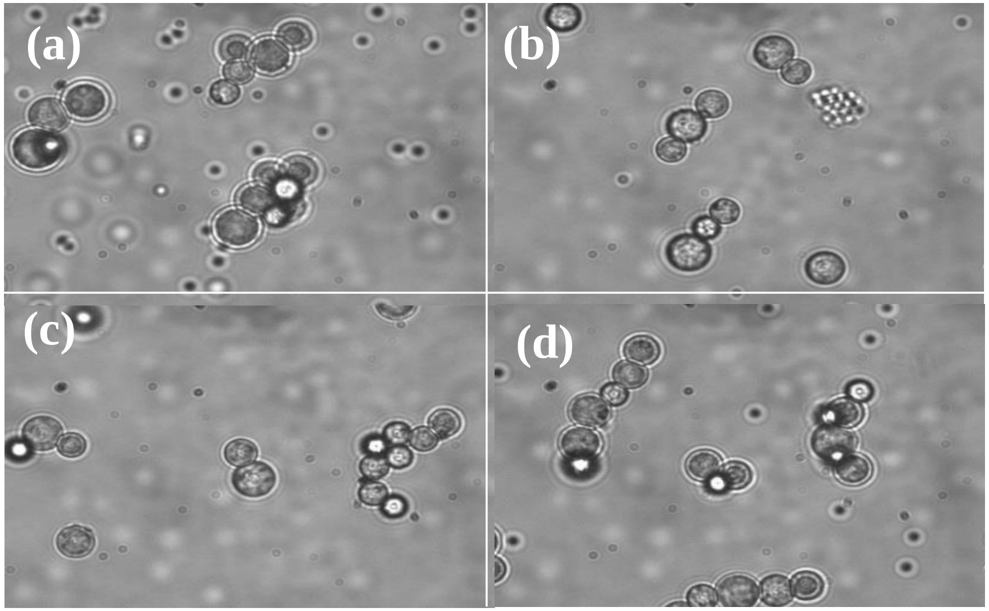
Variation in the initial structures of the FMBs with ferrofluids

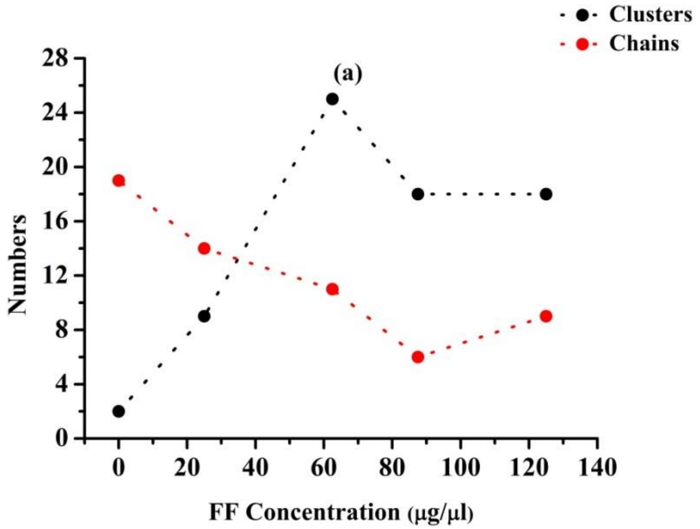


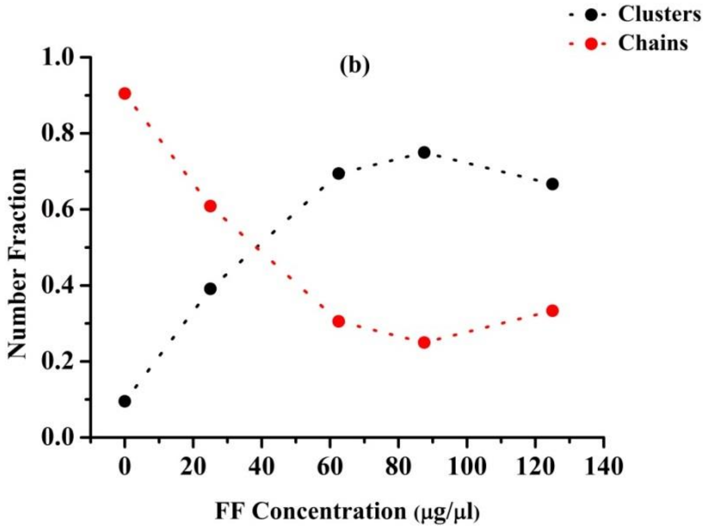




Variation in the initial structures of the PMBs with ferrofluids







How does the variation in the agglomerated structures affect the position fluctuations of the trapped microsphere

- ***Variations in the chain and cluster numbers have a net effect of manipulating the dynamics of the nanoparticles to collectively increase the corner frequency of the trapped non-magnetic bead***

- ***Clusters located at the outer limit of the extent of influence of the OT act as attraction centres for the nanoparticles that are otherwise beyond the influence of the OT***

- ***Within a certain distance from the trap centre, the effect of the electric field gradient is strong enough; ferrofluid particles overcome the magnetic interactions and move under the influence of the electric field gradient of the OT .***

- ***One observes the formation of clusters of PMBs deviating from the original chain structures seen in the absence of FF which when broken into clusters can move much more easily towards the trap centre taking along with them any FF nanoparticles that have accumulated due to the magnetic interaction***

- ***As the FF concentration is increased further, the FF particles themselves participate in the chain re-formation with the PMBs.***

- ***This reduces the availability of the FF particles that can move under the electric field gradient towards the trapped probe thus decreasing the corner frequency values..***

What else has been done

- *Studies with magnetic microbeads and agglomerated structures in the presence of external magnetic fields*

- *Has also be used to sense*

a) *Change in temperature*
b) *Change in viscosity*
c) *Change in chemical environment*

- *Changing the trapped non-magnetic bead to a core-shell magnetic bead gives rise to more interesting dynamics and more possibilities in sensing*

LAB GROUP

Current members

Sarbari Bhattacharya

Shruthi

Chetana

Ashwini

Former members

Sharath Ananthamurthy

Savitha

Rekha

Praveen

THANK YOU