

# Quantum Fluorescent Gold and Superparamagnetic Iron Oxide Nanoparticles for Biomedical Sensing

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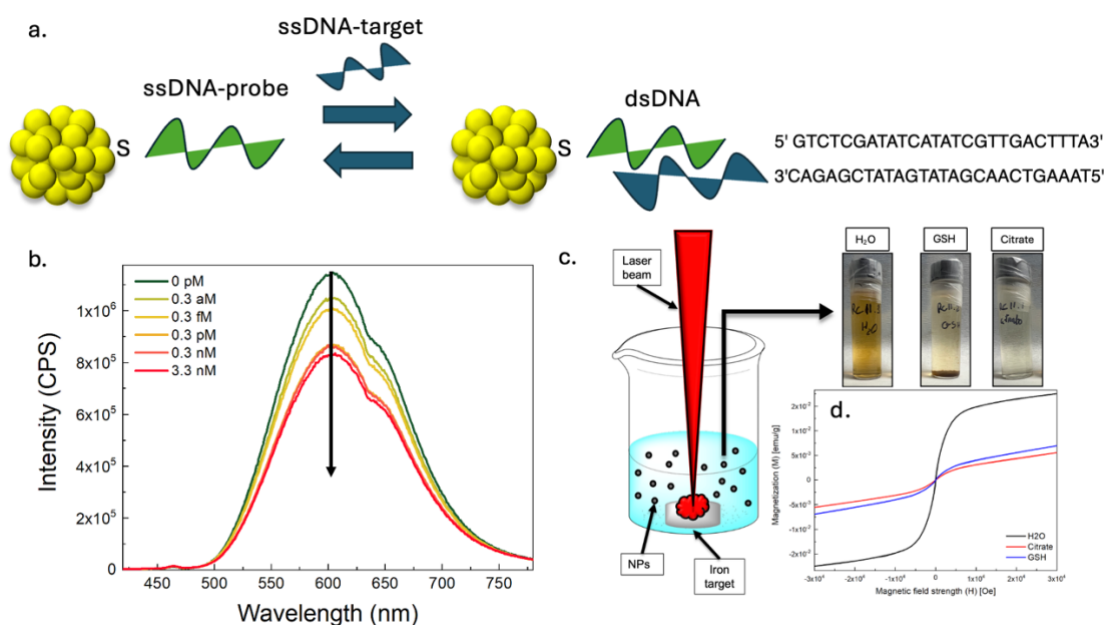
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**Abstract:** By integrating optical and magnetic nanomaterials, this work shows how quantum confinement and surface chemistry enable versatile sensing platforms, combining ultrasensitive fluorescence detection with tunable magnetic responses for sustainable diagnostics and environmental monitoring.

This study, developed within the framework of the National Quantum Science and Technology Institute (NQSTI), presents the activities of UNICT Spoke 7: Complete Quantum Systems, focusing on the exploitation of nanomaterials for advanced sensing and diagnostic applications. In particular, gold nanoclusters (AuNCs) and iron oxide nanoparticles (IONPs) are investigated as model systems to explore how nanoscale quantum effects and surface chemistry can be harnessed to engineer highly sensitive and sustainable sensing platforms.



**Fig. 1** a) Schematic representation of the interaction equilibrium between the two DNA strands of the AuNCs sensor in the presence of complementary DNA. b) Fluorescence spectrum of the AuNCs sensor incubated with different concentrations of

*ssDNA target. c) Schematic representation of the laser ablation in liquid process used to synthesize superparamagnetic iron oxide nanoparticles in different media (H<sub>2</sub>O, GSH, and citrate). d) Magnetization curves of iron oxide nanoparticles synthesized in H<sub>2</sub>O (black), citrate (red), and GSH (blue).*

AuNCs, synthesized through an eco-friendly green chemistry approach [1,2], consist of ~2 nm gold nanoclusters exhibiting size-dependent photoluminescence due to quantum confinement and molecule-like electronic states, with a characteristic absorption band around 400 nm and emission at 600 nm, making them highly attractive for optical sensing applications [3]. Their functionalization with thiolated single-stranded DNA (ssDNA) enables the development of label-free optical sensors capable of detecting complementary DNA sequences via fluorescence quenching. These systems achieve attomolar detection limits with high selectivity, even in complex biological matrices, demonstrating their potential for early diagnostics and molecular sensing. The modularity of the surface functionalization further allows extension to a broad range of molecular targets, including peptides and other biomolecules (Fig. 1a and b).

In parallel, superparamagnetic iron oxide nanoparticles, with an average diameter of ~10 nm, are synthesized via laser ablation in liquid, an emerging and ligand-free technique that enables the production of chemically pure nanomaterials with tunable surface chemistry [4,5]. By performing the ablation in different media, namely water, citrate, and glutathione, a comparative investigation of the role of surface functionalization on colloidal stability and magnetic properties is achieved. The resulting IONPs exhibit superparamagnetic behavior, with distinct magnetization responses depending on the synthesis environment, highlighting the strong influence of surface chemistry on their magnetic characteristics (Fig. 1c and d).

Overall, this work highlights the contribution of nanotechnology to quantum-enabled sensing strategies, bridging fundamental studies of nanoscale physical properties with the development of adaptable and sustainable platforms for diagnostics and environmental monitoring.

### Example References

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