NANO OPTICS AND PLASMONICS

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The main purpose of the following course is to augment the existing course work program of TIFRH and TIFR Mumbai to create a forum for open discussions across a wide platform. The course is modular in structure with flexibility built in the modules in respect of duration, depth and complexity. The flexibity can be used to accommodate a very broad class of participants having different levels of preparation. The course is designed keeping in view the interdisciplinary nature of research activities at TIFR Institutes, so that irrespective of the discipline any researcher can benefit from this course.

Course modules and details

(Note: numbers in brackets denote the tentative hours allocated to discuss all the topics. Bold body text denotes advanced topics).

(1) **Structure and motivation of the course**(1): How NanoOptics meets Plasmonics.
(2) **Introduction to Plasmonics**(7): Plane waves and Gaussian beams; Boundary conditions; Layered media and characteristic matrices; Reflection and transmission through layered media; Dispersion relations; Resonances as the poles of the scattering coefficients; Surface and guided modes; Surface plasmons and coupled surface plasmons; **Avoided crossings;** Resonant tunneling; Wigner delay, Goos-Hänchen shift; **Hartman effect**.
(3) **Introduction to Nano-optics**(5): Near vs far field; Rayleigh limit and how to beat it; Plane wave decomposition of arbitrary beam profile; Near-field superresolution imaging; NSOM.
(4) **Optical properties of composites and metamaterials**(7): **Linear response theory**; optical response of dielectrics and noble metals; Available experimental data and how to use them; Origin of bright coloring of certain metals; Metal dielectric composites; Maxwell-Garnett and Bruggeman theories; Planar composites; Metal inclusion in dielectric host; **percolation threshold**. Metamaterials and negative index materials; Perfect imaging with meta-materials (Pendry lensing); Poor man's perfect lens; **Major hurdles**.
(5) **Localized Plasmons**(4): Resonances of small particles at micro and nano scales; **Mie theory**; Quasistatic approximation and localized modes in small metal particles; Dipolar and quadrupolar modes. **Modes of spheroids and ellipsoids; Shape and size dependence; Polarization aspects of scattering**.

(6) **Patterned nanostructures and metasurfaces**(4) Dolmen structures and Fano resonances; Quasicrystals . Nanofabrication technqiues for large area patterning and testing using spectroscopic techniques to measure the dispersion, plasmon dynamics using time resolved spectroscopy and near-field properties. Quasicrystals and superoscillations. Beating the diffraction limit with propagating waves.
(7) **Other Effects**(5): Extraordinary transmission: Fresnel-Kirchhoff diffraction theory and the flaws in approximations; Bull's eye experiment; **Role of localized and surface modes in extraordinary transmission**. Trapping dielectric and plasmonic micro and nanoparticles: **Exploiting plasmonic nearfield enhancement for trapping / manipulating objects**; **Spin-orbit interaction and optical spintronics.**Light-matter interaction in different regimes covering the weak, strong, ultra- and deep strong coupling regimes. Examples.
(8) **Applications**(5): Plasmonics for sensing; Surface and nanoparticle enhanced spectroscopy; **Single molecule spectroscopy**; **Photothermal therapy of cancer**; Plasmon mediated chemical reactions and catalysis; Plasmon mediated non-linear signal enhancement; SPASERs and Nanolasers; **Nanofiber mediated entanglement**, single photon emitters.

1. Suggested Books and Notes

(1) S Dutta Gupta, N Ghosh and A. Banerjee, *Wave Optics: Basic Concepts and Contemporary Trends*, (CRC Press, New York, 2015).
(2) H Raether, *Surface plasmons on smooth and rough surfaces and on gratings*, (Springer, New York, 1988).
(3) L Novotny and B Hecht, *Principles of Nano-Optics*, (Cambridge, NewYork, 2006).
(4) W Cai and V Shalaev, *Optical Metamaterials Fundamentals and Applications*, (Springer, NewYork, 2010).
(5) S Maier, Plasmonics *Fundamentals and Applications* (Springer, UK, 2007).
(6) J P Fillard, *Near Field Optics and Nanoscopy*, (World Scientific, Singapore, 1998).
(7) Venu Gopal Achanta, Plasmonic Quasicrystals, Prog. Quantu. Electronics **39**, 1-23 (2015).
(8) Venu Gopal Achanta, Surface waves at metal-dielectric interfaces: Material Science perspective, Reviews in Physcs **5**, 100041 (2020).
Note that whenever needed research articles will be used. There may be a laboratory componet at TIFR Mumbai if the COVID situation improves.