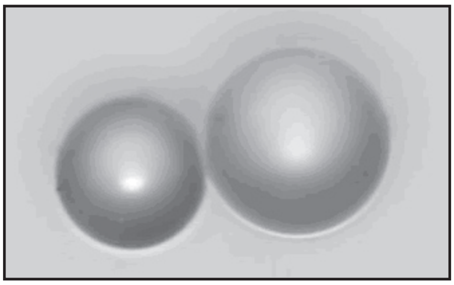
Tyndall National Institute
Institiúid Náisiúnta

Quantum Optics

Exploring the boundaries between the classical and quantum world

The Quantum Optics group was created in September 2003 in Cork Institute of Technology, through funding by Science Foundation Ireland. The core work of the group involves the study of evanescent field optics to develop novel laser systems and to study light-matter interactions using laser-cooled rubidium atoms. The group is affiliated jointly with the Department of Applied Physics and Instrumentation, Cork Institute of Technology and Tyndall National Institute.

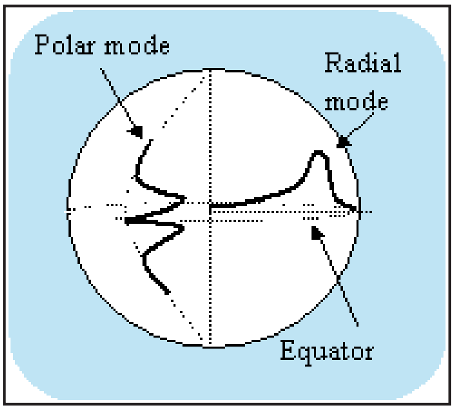


Above: Image of two ZBNA microspheres. Diameters of approximately 60 and 80 micron.

Microcavity lasers and evanescent field optics

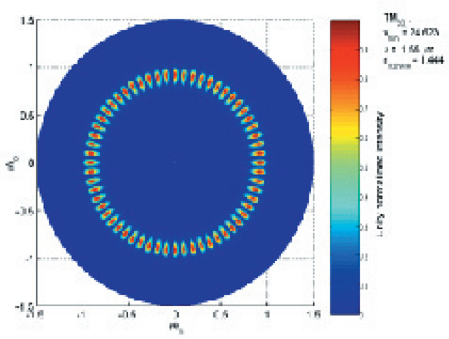
The group is investigating microspherical lasers fabricated from erbium-doped ZBNA and commercial erbium/ytterbium co-doped IOG2 glass. The ZBNA material is a novel material with properties similar to that of ZBLAN – a material of choice for fibre communications technologies. Applications of such microlasers are wide ranging; from biosensors, to acceleration sensors, to add-drop filters in communication networks. The group is exploring the behaviour of microcavity lasers pumped at 980 nm with emissions in the 520 nm, 540 nm and 1.56 micron regions.

In a microsphere, light propagates around the equator in whispering gallery modes. In a geometrical optics picture, this can be viewed as multiple total internal reflections on the sphere-air interface. A realistic mathematical description of the electromagnetic field patterns in a microsphere begins with the solution of the Helmholtz equation in spherical coordinates. The excited modes can be described by three mode numbers n, l and m, and the polarisation TE or TM.

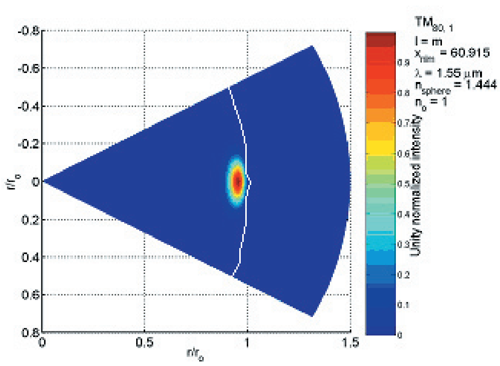


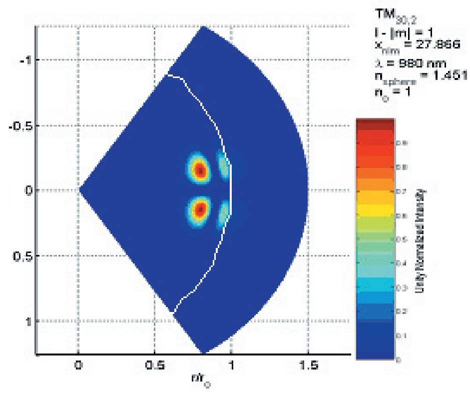
Above: Representation of the whispering gallery modes in a microsphere.

The quantum mechanical analogy assumes an effective radial potential, comprising of the well potential and centrifugal potential at the surface of the sphere. This ensures that the propagating photons remain confined to the well near the sphere surface. Classically, as long as the energy of the bound state photon is below the level of the potential barrier the photon cannot leak out of the potential well and into the forbidden regions. In reality, the wave function has a non-zero probability outside the potential well, thus giving rise to whispering gallery mode losses and an evanescent tail extending beyond the surface of the sphere. Pump light is coupled into the whispering gallery modes through the evanescent field via an optical fibre that is heated and pulled to a taper of a few micron in diameter.



Above: Intensity distribution of a standing wave in the equatorial plane for a n = 1 resonance mode.





Above: The modes for n = 1 are closer to the surface than for n = 2.

Light-matter interactions

We are using laser cooling to trap 109 rubidium atoms in a magneto-optical trap. Average atom temperatures of about 50 mKelvin are achieved through this technique. The cold atoms are used to investigate light-matter interactions; these studies are facilitated by the fact that the atom energy is reduced through the laser cooling and, therefore, the atoms are moving at a much lower velocity than for a normal gas. This allows for increased interactions times and opens many avenues for manipulating the atoms that would otherwise not be feasible. In particular, we are studying the interactions between atoms and the evanescent field emitted from optics components e.g. a tapered fibre. By monitoring the light transmission through the taper we should be able to determine whether the atoms have interacted with the on-resonant evanescent field beyond the surface boundaries. Later studies will incorporate a microsphere into the setup.

We are also theoretically investigating the generation of a coherent superposition of a single atom using a multi-trap configuration. We use an atom optics analogue to the generation of a superposition of atomic states using a STIRAP type process in a L-configuration where the final state is twofold. We have shown that it is possible to create two orthogonal, maximally coherent superposition states with equal amplitude but inverse relative phase.

These projects will yield invaluable information on the manipulation and control of cold atoms (i.e. quantum engineering) with applications in quantum information technologies.

Collaborators:

Dr. Patrice Féron, ENSSAT, Lannion, France.
Prof. Shiqi Jin and Prof. Shangqing Gong, SIOM, CAS, Shanghai, China.
Dr. Thomas Busch, School of Physics, Dublin Institute of Technology and Physics Department, University College Cork.

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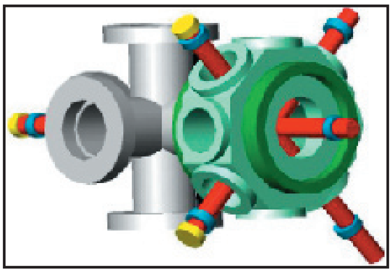
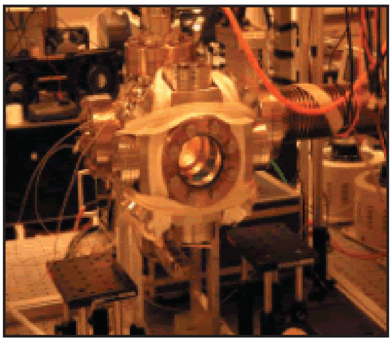
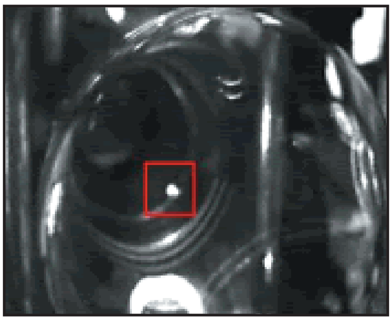
- Science Foundation Ireland
- The Royal Irish Academy
- Cork Institute of Technology
- IRCSET
- The Council of Directors of the Institutes of Technology

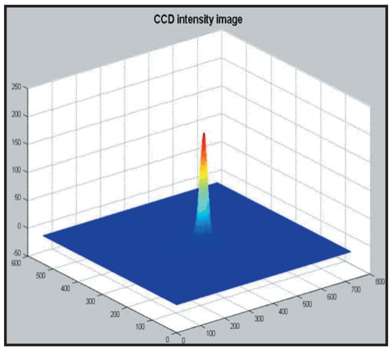
Above: Research at Quantum Optics is made possible by funding and participation from these organisations





Above: Schematic representation of the magneto-optical trap and a photograph of the actual setup





Above The cloud of cold rubidium atoms is imaged using a CCD camera. The size of the cloud is determined by fitting a Gaussian curve to the intensity profile.

For More Information on these topics contact:

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