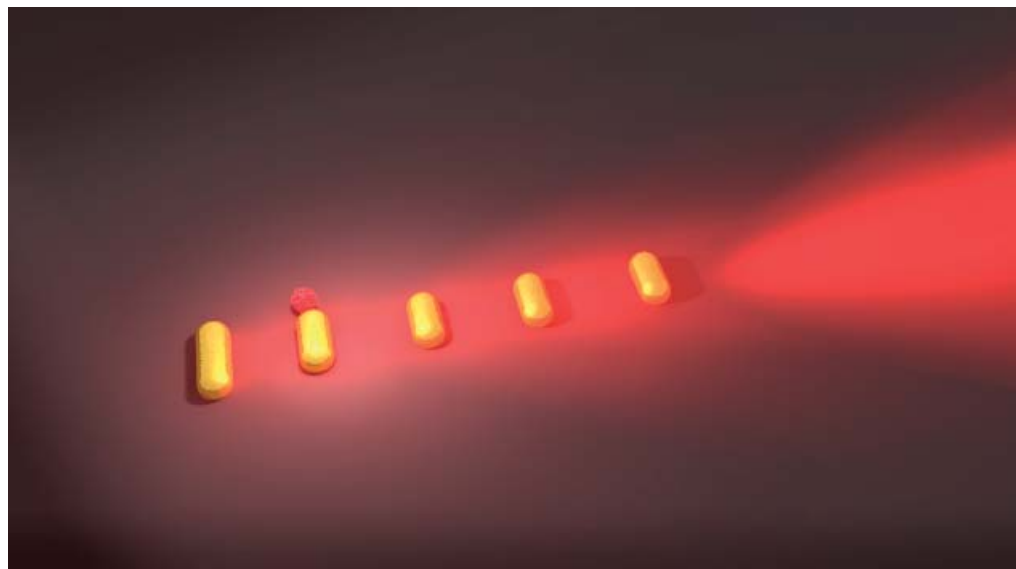


## Control of single quantum emitters by phase shaped excitation and optical antennas



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We describe experiments employing femtosecond pulse-shaping techniques by which quantum coherences in single organic molecules can be created, probed, and manipulated at ambient conditions even in highly disordered solid environments. We couple individual molecules reversibly to an optical monopole antenna and achieve control of the emission direction.

**Special Time and Location**  
**11:00 am, Monday, Nov 29, 2010**  
**Goergen 108**  
Refreshments provided.

# Control of single quantum emitters by phase shaped excitation and optical antennas

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**Abstract:** Coherence does play a role in achieving the high efficiencies of light-energy conversion in natural antenna complexes. However since natural systems are intrinsically heterogeneous, clear relations between structural and quantum properties can only be obtained by addressing individual systems. Here we show by employing femtosecond pulse-shaping techniques that quantum coherences in single organic molecules can be created, probed, and manipulated at ambient conditions even in highly disordered solid environments [1]. We find vibrational wave-packet interference and broadly distributed coherence decay times for different individual molecules giving direct insight into the structural heterogeneity of the local surroundings. A superior degree of coherent control is achieved by adapting the time and phase distribution of the optical excitation field to the dynamics of each molecule.

The efficient optical excitation and detection of nanoscale quantum emitters generally involves large solid angles because their interaction with freely-propagating light is omni-directional. Unidirectional emission of a single emitter can be achieved by coupling to a nanofabricated optical antenna [2]. We have placed quantum dot in the near field of the antenna, such that it drives the resonant feed element of the antenna. The resulting quantum-dot luminescence is strongly polarized and highly directed into a narrow forward angular cone. The directionality of the quantum dot can be controlled by tuning the antenna dimensions. Similarly we couple individual molecules reversibly to an optical monopole antenna [3] and achieve control of the emission direction. Moreover the direct mapping of the antenna field with single fluorescent molecules reveals a spatial localization of 25 nm, demonstrating the importance of such antennas for nanometer resolution optical microscopy [4]. Our results show the potential of optical antennas to communicate energy to, from and between nano-emitters.

1. D. Brinks, F. D. Stefani, F. Kulzer, R. Hildner, T. H. Taminiau, N. F. van Hulst, “Visualizing and controlling vibrational wave packets of single molecules”, *Nature* **465**, 905-908 (2010).
2. A.G. Curto, G. Volpe, T. H. Taminiau, M. Kreuzer, R. Quidant, N. F. van Hulst, “Unidirectional emission of a quantum dot coupled to an optical nanoantenna”, *Science* **329**, 930 (2010).
3. T.H. Taminiau, F.D. Stefani, F.B. Segerink, N.F. van Hulst, “Optical Antennas direct Single-Molecule Emission”. *Nature Photonics*, **2**, 234 (2008).
4. T.H. Taminiau, R.J. Moerland, F.B. Segerink, L. Kuipers and N.F. van Hulst, “ $\lambda/4$  Resonance of an Optical Monopole Antenna Probed by Single Molecule Fluorescence”, *NanoLetters* **7**, 28-33 (2007). [highlighted in *Nature Photonics* **1**, 90 (2007)].

**Biography:** Obtained his PhD (1986) in Molecular and Laser-physics at the University of Nijmegen (the Netherlands). After research in non-linear optics, organic materials, integrated optics and waveguides, in 1990, he became an Assistant Professor at the University of Twente, working on near-field optical & atomic force microscopy, non-linear optics and hyper Raleigh scattering. In 1997 he became full Professor in Applied Optics, at the MESA+ Institute for NanoTechnology (Enschede, the Netherlands), with focus on single molecule detection, nanophotonics, photonic structures, scanning probe technology, applications in molecular biology and chemistry. Since September 2005, he is ICREA Research Professor at ICFO – the Institute of Photonic Sciences – Barcelona (Spain), as a senior group leader in NanoPhotonics, working on nanoantennas, single photon emitters, ultrafast detection and phase control on the nanoscale. Recipient of the 2009 ERC Advanced Investigator Award; 2003 European Science Award (Körber foundation, Hamburg) and 1997 Shell Research Stimulation Award. Since 2007 he coordinates the national Spanish CONSOLIDER program “NanoLight.es – light control on the nanoscale” (2007-2012), involving 10 groups in nanophotonics/plasmonics.