of the potential disappears. This temperature correspond to a power of $81271$ of $+1$ GHz, we find the optimal trap potential can be formed if $a \approx 10$ nm. In this case, the minimum level of the trap potential is found at a distance $60$ nm from the surface of the tip, as shown in Fig. 3. The atom can be trapped at one of the quantized vibrational levels with $n$ above the kinetic energy of $30$ p.K in terms of the trap potential, the minimum level with $n=10$ nm. In this case, the trap potential becomes too shallow to trap a Rb atom by conventional laser cooling techniques. On the other hand, the signal remains above the $100$ nm mark, the van der Waals force in a certain condition.

It has been proposed that an atom can be trapped at a minimum point of a trap potential composed of the repulsive dipole force and the attractive van der Waals force in a certain condition. To generate a stable trap potential for a Rb atom, we must pay attention to several parameters: van der Waals force, de Broglie wavelength and radius of the aperture. Here, in order to estimate the near-field optical potential for a Rb atom, we assume that the experimentally obtained function $l(r)$ can be applied to the case where the tip radius is smaller than $80$ nm. When we consider the case of the optical near field power of $80$ W/cm$^2$ and the frequency detuning of $8/2\pi$ of $+1$ GHz, we find the optimal trap potential can be formed if $a = 10$ nm. In this case, the minimum level of the trap potential is found at a distance $60$ nm from the surface of the tip, as shown in Fig. 3. The atom can be trapped at one of the quantized vibrational levels with $n$ above the kinetic energy of $30$ p.K in terms of the trap potential, the minimum level with $n=10$ nm. In this case, the trap potential becomes too shallow to trap a Rb atom by conventional laser cooling techniques. On the other hand, the signal remains above the $100$ nm mark, the van der Waals force in a certain condition.

Nowadays, a measurement of the intensity of the optical field in integrated optical waveguide devices with a photon scanning tunneling microscope (PSTM) is reasonably routine. However, if one could visualize the evolution of the phase of the light field in real-space, it would yield new and detailed information concerning the properties of wavelength multiplexers, mode converters, etc., of which the operation depends critically on the phase of the field. Here, we believe we present the first phase mups of light in integrated optical waveguides obtained with a heterodyn interference PSTM.

A PSTM is based on the principle of frustration of the evanescent field at an air-waveguide interface when a optical fiber tip is brought in the near-field (a few nanometers) of this interface. The nonpropagating evanescent wave is locally converted into a propagating wave and guided through the fiber. Maps of the relative phase of the optical field have been recorded by including the PSTM in one branch of a Mach–Zehnder interferometer. The photon-tunneling signal and the reference signal interfere in a $3\mu$m fiber coupler and this interference signal is detected with a photon multiplier tube. Acousto-optic heterodyne detection of the phase with a frequency of $40$ kHz is used to detect the photon-tunneling signal. Through the use of both the in- and out-of-phase outputs of a lock-in amplifier, we can calculate the (cosine of the) phase and the amplitude of the optical field in the waveguide. By raster scanning the tip over the waveguide a phase map is obtained.

Figure 1 shows a phase measurement of a light $(\lambda = 632.8$ nm) in a channel waveguide. Linear polarized light has been coupled in a controlled way in the input facet of the waveguide in order to simultaneously excite both $TM_{04}$ and $TM_{02}$ modes. The topography is shown in Fig. 1(a), the amplitude and the phase of the optical field in Fig. 1(b) and 1(c), respectively. With the PSTM both TE- and TM-polarized light is detectable. As a result, two modes with orthogonal polarization produce a detectable beating pattern. This pattern is observed in the amplitude map of Fig. 1(b). Surprisingly, the phase image contains phase singularities at various positions [indicated with the arrow in Fig. 1(c)].

The first phase measurements of the optical field in integrated optical waveguides have been performed with an interferometric PSTM. Because of so-called mode beating the phase exhibits singularities. Calculations show that these singularities occur at locations where the amplitudes of the modes are exactly equal and the modes are exactly out-of-phase.


3. M. Ohtsu, S. Jiang, T. Parangbuan, M. Kozuma, "Interferometric PSTM measurement of a Si$_3$N$_4$ channel waveguide. The width and the height step of the waveguide are 2.86 $\mu$m and 4.2 $\mu$m, respectively. (a) Measured topographical image. (b) The measured amplitude of the optical field of the modes inside the waveguide. (c) The measured evolution of the cosine of the phase of the optical field. The arrow indicates a phase singularity."

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Near-field spectroscopy of surface excitations

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Correlations and spectral properties of thermal light have been the subject of many studies since the development of statistical optics and modern coherence theory.1,2 In most of the studies, the non-radiating (near field) part of the emitted light is disregarded, because it plays no role in the far-field emission properties of planar sources. Nevertheless, recent interest in microscale and nanoscale radiative transfer,1 together with the development of local-probe thermal microscopy2 and the observation of coherent thermal emission from doped silicon and silicon carbide (SiC) gratings3 have raised new challenges. In fact, all these topics have in common the substantial role of the non-radiating (evanescent) thermal fields.

Spatial correlations of the near field thermally emitted by a planar opaque surface were studied recently. The strong influence of the non-propagating components of the field was put forward. In particular, it was shown that resonant surface excitations (surface-plasmon or surface-plasmon polaritons) lead to long-range spatial correlations.4 This phenomenon is at the origin of spatially coherent thermal emission of doped silicon and SiC gratings5 in this work, we concentrate on the spectral properties of the thermally emitted near field. Our approach is based on fluctuational electrodynamics and the fluctuation-dissipation theorem.6 The basic quantity to compute is the cross-spectral density tensor of the electric field:

\[
\langle E_{x}(r, \omega) E_{y}^{*}(r', \omega') \rangle = W_{xy}(r, r', \omega, \omega') \times \delta(\omega - \omega') ,
\]

where \(E_{x}(r, \omega)\) is the time-domain Fourier transform of the electric field and the brackets denote an average over the ensemble of realizations of the field. The electric energy density is obtained by:

\[
U_{e}(r, \omega) = \sum_{n} W_{n}(r, r', \omega, \omega') .
\]

The method leads to an exact expression of the energy density \(U_{e}(\omega)\), which is valid in both near field and far field. In particular, the role of the interface and the existence of surface electromagnetic modes is taken into account.

We show that near-field excitations dramatically influence the spectrum of the emitted radiation. For example, we study a SiC surface in the infrared part of the spectrum. The energy density has a spectrum which changes strongly during the transition from the near field to the far field (Fig. 1). The near-field spectrum is a signature of the excitation of surface-phonon polaritons at wavelengths around \(\lambda = 11.3\ \mu m\). We show that the features of this spectrum can be interpreted using the density of states of the surface modes. This work provides a powerful tool to describe near-field spectroscopic effects in thermal emission of light. Due to the possibility of measuring near-field spectra by using near-field optical techniques, this work could find applications in solid-state spectroscopy. It should also be helpful in modeling nanoscale radiative transfer of energy, where transfer through non-radiating modes is of fundamental importance.

"Univ. of Rochester, USA"


QMF8 NOON

Quantum jumps of individual emitters in a heterogeneous environment studied by near-field optics

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We have performed real-time and orientation resolved measurements of single fluorescent molecules (DIIc<sub>e</sub>) in thin films of PMMA and polystyrene at ambient and reduced oxygen conditions. Fluorescent time trajectories of single molecules have been recorded using a two-channel near-field optical microscope, with 30-µm real-time resolution.

A typical fluorescence trajectory is shown in Fig. 1, covering 3.5 sec with 5 orders of magnitude dynamic range. Real-time single-triplet jumps (S-T-T) are directly observed.

We find that both triplet state lifetime and crossing yield vary in time due to the local heterogeneity of the polymer host. A triplet lifetime distribution, both in space and in time, is constructed from the data. The triplet lifetime distribution for PMMA peaks at 180 µs with 130-µs FWHM, as compared to 50 µs, 20-µs FWHM, for polystyrene. The main cause is a difference in oxygen solubility and mobility, as confirmed by varying the oxygen concentration of the sample. Within the triplet lifetime we determine an average number of collisions with oxygen of 3 and 11 for PMMA and polystyrene, respectively.

The inter-system crossing yield appear to be hardly correlated to the triplet lifetime, with only weak effect of the presence of oxygen.

Photo-dissociation occurs after emitting 10<sup>6</sup> or 10<sup>7</sup> photons typically for PMMA and polystyrene, respectively. Dissociation due to singlet oxygen would be most likely. Yet, again the dissociation probability shows no correlation with triplet lifetime or inter-system crossing yield for either of the investigated environments, in contrast to other observations.

Finally discrete rotational jumping between two conformationally defined orientations is observed.

New insight in the photo-dynamics and orientational mobility of individual molecules is obtained using single molecule detection: time-varying heterogeneity, correlations and distributions of photo dynamic parameters.