Near-field control and switching of an optical signal

Benoit Cluzel, Loïc Lalouat, Philippe Velha, Emmanuel Picard, David Peyrade, Jean-Claude Rodier, Thomas Charvolin, Philippe Lalanne, Emmanuel Hadji, and Frédérique de Fornel

Bringing a nanoscale tip into the evanescent near field of a nanocavity shifts the resonance and allows switching of photon transmission.

In conventional electronics, information is encoded in the flow of electrons, which is modulated or switched on and off by field-effect transistors (i.e., typical devices) on a semiconductor chip. In long-distance telecommunications, however, information is carried by light. Making a nanoscale device that can control the flow of photons on a chip has been a long-standing goal.

To meet this objective, one must both localize photons at a subwavelength scale and locally modify their propagation. Such modification has traditionally been achieved by tuning material properties, for instance by thermo- or electro-optic effects.\(^1\)\(^-\)\(^3\) Recently, we demonstrated that switching and tuning can be achieved without changing the material properties, by bringing a sharp tip into the evanescent near-field region of a nanoscale optical cavity, as shown in Figure 1.

The possibility of near-field modulation has been investigated theoretically\(^4\) and experimentally.\(^5\)\(^,\)\(^6\) Previously, however, switching was achieved at the expense of a drastic decrease of the quality factor, \(Q\), of the cavity. The resulting interaction merely washes out the resonance, rather than tuning it away from the signal wavelength, \(\lambda\).

In contrast, we operated in a regime of weak tip–cavity interaction. We demonstrated 0.8nm tuning of the resonance wavelength in a high-\(Q\), small-volume nanocavity—volume\(\approx\)0.6(\(\lambda/n\))^3, where \(n\) is the refractive index—created in a silicon-on-insulator waveguide. We observed a reversible 14dB switching operation of the cavity transmittance, as shown in Figure 2.\(^7\)

Even at this early stage of development, we believe that this device may find use in a broad range of applications. Since its tuning range is compatible with the interchannel wavelength spacing in wavelength-division multiplexing (WDM) telecommunications systems, it can be used for building electromechanical routers. The switching speed of such devices will

Figure 1. Schematic view of cavity tuning by a nanoscale tip. Bringing the tip into the optical near field of the cavity results in a redshift of the cavity resonance wavelength from \(\lambda_{up}\) to \(\lambda_{down}\).

Figure 2. Observed switching of the transmitted light intensity \(I_T(t)\) through the cavity-tip nanosystem as the tip–cavity distance \(Z(t)\) varies. The light wavelength \(\lambda = \lambda_{up}\). At \(t=0\), the tip is away and the transmittance is maximum. When the tip is close to the surface, for example at \(t=0.1\)s, the transmittance is strongly reduced.

Continued on next page
be limited by mechanical resonance frequencies, which with miniaturization could exceed the megahertz range.  

This work was supported by the Bourgogne region and research ministry: ACI (concerted initiative) no. 63.

Author Information

Benoit Cluzel, Loïc Lalouat, and Frederique de Fornel  
Equipe Optique de Champ Proche  
ICB UMR 5209  
Dijon, France

Philippe Velha, Emmanuel Picard, Thomas Charvolin, and Emmanuel Hadji  
Laboratoire Charles Fabry de l’Institut d’Optique  
CNRS, Campus polytechnique  
Palaiseau, France

Département de Recherche Fondamentale sur la Matière Condensée  
French Atomic Energy Commission (CEA)  
Grenoble, France

David Peyrade  
Laboratoire des Technologies de la Microélectronique  
CNRS  
Grenoble, France

Jean-Claude Rodier and Philippe Lalanne  
Laboratoire Charles Fabry de l’Institut d’Optique  
CNRS, Campus polytechnique  
Palaiseau, France

References