

A Magnetic Monopole Antenna

Magnetic monopoles are theoretical particles characterized by a singular magnetic pole, distinct from common magnetic entities that manifest as pairs of magnetic poles. The notion of magnetic monopoles originated with Paul Dirac in the 1930s, sparking substantial theoretical and experimental exploration in subsequent decades. Despite extensive investigation, definitive observational evidence of magnetic monopoles in the cosmos remains elusive.
In recent times, diverse methodologies have been suggested to investigate magnetic monopoles, encompassing high-energy particle accelerators, cosmic ray detectors, and the exploration of potential «traces» in specific materials. In pursuit of advancing these efforts, researchers at INSP, in collaboration with counterparts at the Institut Langevin, have introduced a novel electromagnetic antenna designed to emulate the behavior of a magnetic monopole.

Indeed, 135 years after Heinrich Hertz's pioneering work on radio antennas, researchers have demonstrated that a seemingly simple structural element—a slit in a semi-infinite metal layer—can effectively amplify the local magnetic field. This augmentation in energy density within the optical magnetic field is characterized by a singular orientation, representing a distinct magnetic pole, in contrast to dipoles with opposing poles.

The researchers further detail the temporal oscillation of this monopole, which alternates between north and south orientations. This distinctive behavior enables the antenna to efficiently emit light from this solitary pole, akin to the operational principle observed in electric monopole antennas commonly employed in telecommunications.

Moreover, the researchers validated the universality of this behavior across the entire electromagnetic spectrum, encompassing ranges from ultraviolet to GHz frequencies. To conclusively establish the magnetic monopole nature of this structure, Gauss's theorem was applied to the optical magnetic field, revealing the unequivocal presence of a singular magnetic charge at the core of the antenna. This identification of a magnetic charge holds notable implications, particularly regarding the potential for locally manipulating the material's magnetic permeability. This opens avenues for manipulating the optical index on the nanoscale, presenting significant opportunities for practical applications.

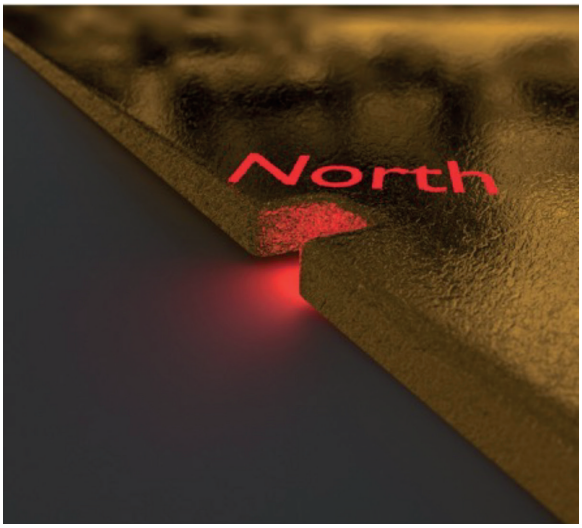

Figure
Une nanostructure photonique créée dans une couche d'or semi-infinie présente le comportement d'un monopôle magnétique, ayant un unique pôle de champ magnétique orienté dans une seule direction et contenant une charge magnétique unique en son sein.

These findings present a novel paradigm for the fundamental exploration of magnetic monopole particles. Additionally, they introduce a versatile tool with broad applications across various domains in both research and industry, spanning the nanoscale to macroscopic levels. This tool finds relevance in diverse areas such as the investigation of light-matter interactions, experimentation in nanoscale nuclear magnetic resonance, the formulation of negative-index metamaterials, and the development of innovative radio-frequency systems for applications in telecommunications and medical imaging.

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Reference
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