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Bundt-pan antenna can concentrate optical infrared energy onto nano-sized detectors

Optical infrared detection devices are becoming smaller in size with tiny active areas in the range of a few micrometers or even nanometers, such as photodetectors, solar cells, cameras, and microbolometers. Such miniature size gives several advantages to an infrared detection device, for example, ultrafast optical response, low operating temperature, efficient cooling, efficient generation/ collection of photo-carriers, small pixel-size for high spatial resolution imaging, and the possibility of ultra-dense integration with other devices. However, all of that comes at the expense of a smaller device aperture area, and in turn inefficient collection of infrared energy. Which may jeopardize all of the miniaturization advantages.

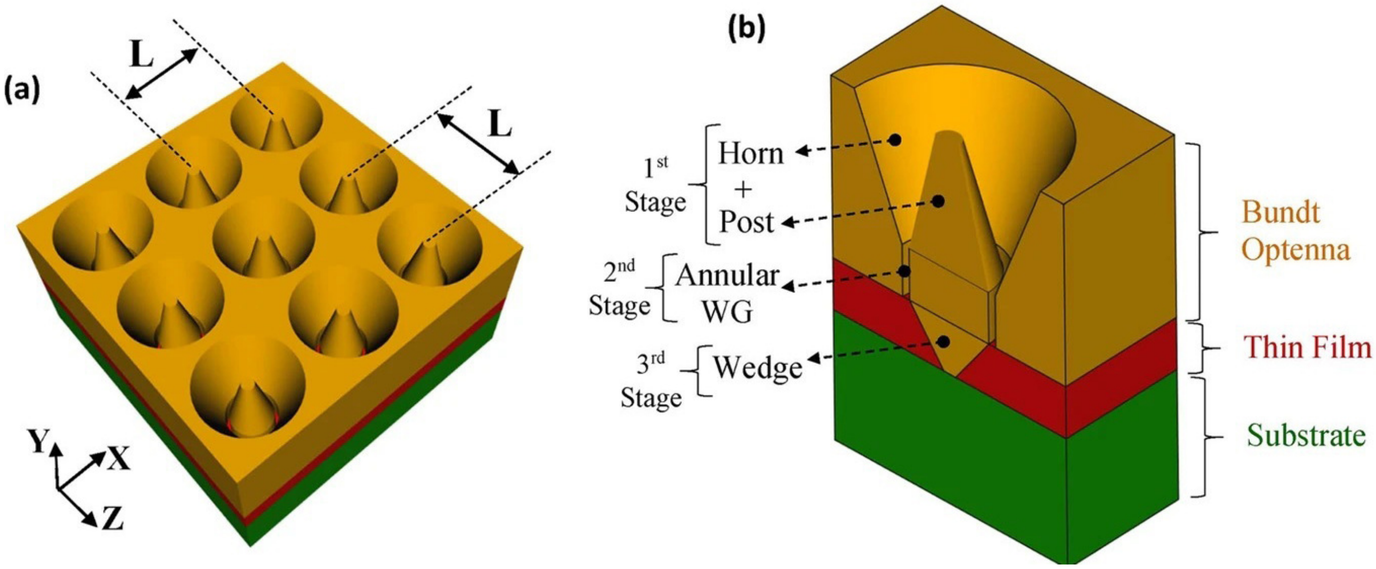

Fig. 1. The Bundt optenna structure: (a) A perspective view of the two-dimensional unit-cells periodic array, (b) A vertical cross-section of one unit-cell indicating different stages.

Bundt-pan-shaped optical antenna (optenna) is one of the key solutions to increase nano-detectors aperture areas. It can collect infrared energy from all over the space and squeeze it down to the nano-sized area of the detector aperture. That is because of its coaxial and conical horn shape, which is followed by the optical-impedance matching waveguide stage, and then a gold wedge stage that increases the penetration depth of squeezed infrared inside the thin-film detection material (Fig. 1). The Bundt optenna unit cells are arranged in a periodic array that is placed on top of an infrared thin-film absorbing layer. The Bundt optenna utilizes surface plasmons to squeeze both electric and magnetic fields of infrared radiation down to a 50-nanometer wide-area (Fig. 2). Thus, it can enhance the absorption efficiency of the thin-film detection layer by 10^8 times.

The Bundt optenna can collect any polarization of free-space infrared radiation. It can collect energy from within 80^o wide angle of view in front of the horn. It covers a wide range of bands including the near, short, and middle infrared bands. All of that comes with reasonable plasmonic power losses on Bundt gold sidewalls. The size of the Bundt optenna is compact and relatively small when compared to the infrared wavelength, and thus it is suitable to be placed on miniature infrared detectors.

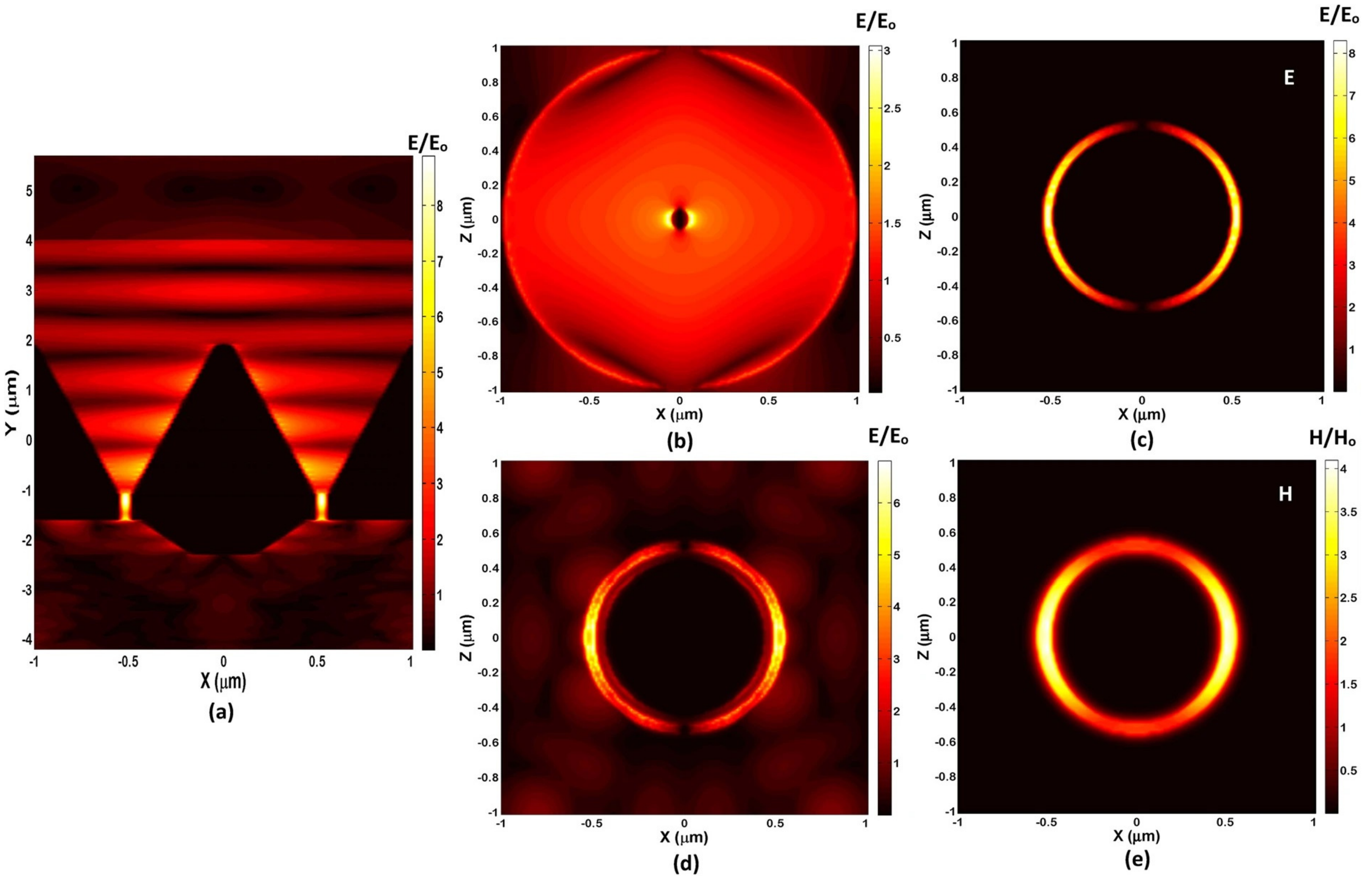

Fig. 2. The infrared fields (E: electric field, H: magnetic field) across a Bundt unit-cell: (a) A vertical cross-section in the whole Bundt unit-cell, (b) A horizontal cross-section at the horn input, (c) A horizontal cross-section at the waveguide input, (d) A horizontal cross-section at the waveguide output, (e) A horizontal cross-section at the waveguide input showing the H-field.

The Bundt optenna can improve the detectors' quantum efficiency, responsivity, and sensitivity. It is promising for various nano-scale infrared detection devices such as photodetectors, solar cells, cameras, and microbolometers, with applications in optical communications, energy harvesting, imaging, sensors, and biomedical technology.

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