Compact, all-optical, Terahertz wave generator

Terahertz (THz) wave is a kind of invisible light that has the frequency of about 10^{12} Hz. THz wave can path through different materials with small absorption or reflection, therefore this kind of wave can be used for imaging behind the cloths, skin or inside the boxes that have important applications in medical or security imaging. Also THz waves can be used for communication with higher capability and security than radio waves.

Up to know various methods have been used for THz waves generation, however achieving an efficient, compact, low cost and tunable THz sources are still one of the challenges to the developing of this technology. We proposed and designed a new THz source that can meet some of the mentioned challenges by combining a single graphene layer and a photonic crystal (PhC).

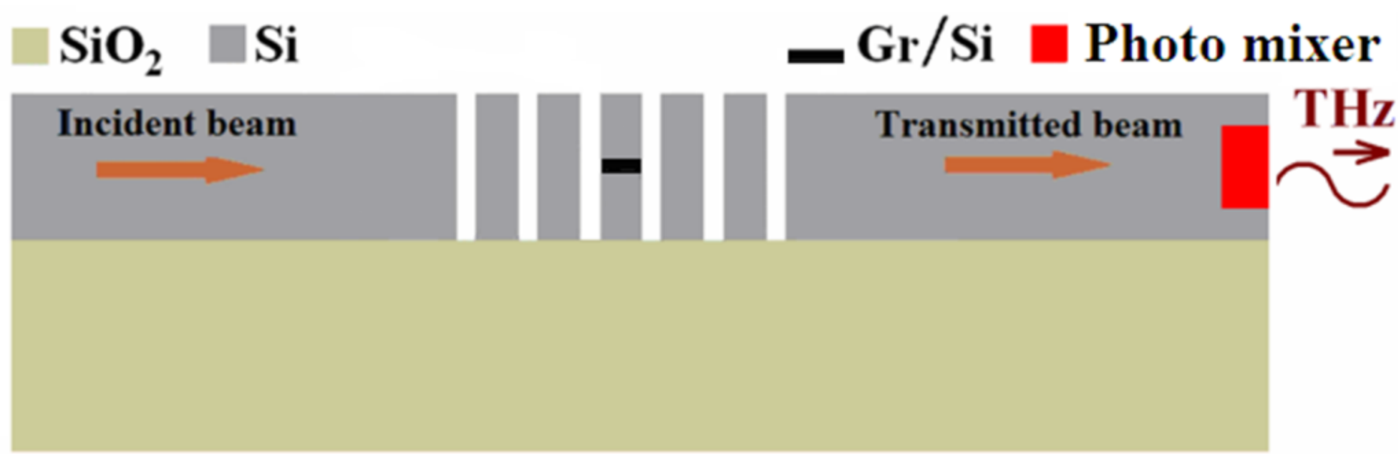

Fig. 1. Schematic of the THz wave generator. It consists of a Si PhC and a graphene (Gr) layer. A constant-intensity optical light is inputted from the left hand side, modulated in the cavity at the graphene layer, and converted to THz wave by a photo mixer at the right-hand side.

PhCs are periodic structures that can control various features of propagating light inside them and graphene is a single atomic layer of carbon. Graphene is a new discovered structure of carbon that has various interesting electrical and optical features. One of the interesting properties of graphene is its high optical nonlinearity with the change of light intensity.

The schematic of the proposed THz wave generator is shown in Fig. 1. The structure consists of a thin-layer one-dimensional silicon (Si) PhC with a period length of about 1 micrometer (10^{-6} meter) that includes a single layer of graphene in the middle cell of the PhC. We used an incident light wave with a constant intensity and a wavelength of about 1.5 micrometers. This wavelength is used due to its common application in optical communications.

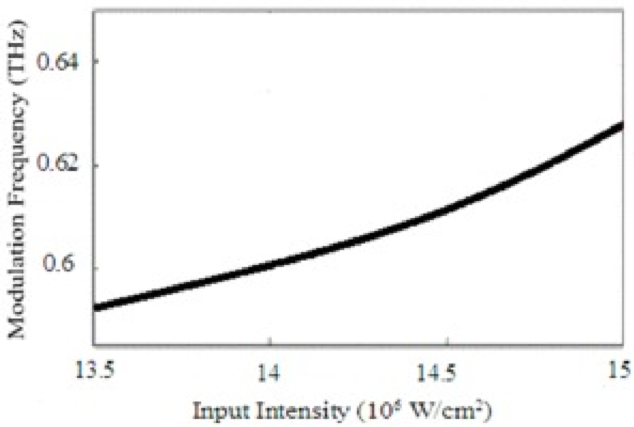

Fig. 2. The modulation frequency versus average intensity of the incident light

By optimizing the PhC characteristics we design a cavity in the PhC to be in resonance to the incident light. The resonance leads to enhancement of the inside intensity and thus changing the optical properties of the graphene layer, leading the cavity to deviate from resonance and the reduction of the inside intensity. As a result, the graphene returns to its initial state a short moment later and the cavity also returns to its initial resonance condition at the same time. This leads to a periodic process of resonance and non-resonance in the cavity, leading to a periodic output intensity.

The modulation frequency depends on the PhC and input light properties and is in the range of THz. Finally the PhC output, which is a light with an intensity modulation in THz frequency, is converted to THz wave in free space by using standard methods (such as photonic mixer).

In addition to its compactness, the important feature of the proposed THz source is its low-cost tuning method of modulation frequency: by only tuning of the input intensity in the range of 13.5 to 15 Megawatt/ cm^2, the modulation frequency can be tuned more than 5% around ~0.6 THz, as can be seen in Fig. 2.

Publication

A compact, all-optical, THz wave generator based on self-modulation in a slab photonic crystal waveguide with a single sub-nanometer graphene layer.
Asadi R, Ouyang Z, Mohammd MM.
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