Tunable Terahertz Difference Frequency Generation With 1550nm Fiber Laser

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Abstract----**Terahertz (THz) generation, using the Difference Frequency (DF) effect, is a promising way to develop a THz source. Dual-wavelengths laser, having stable phase and with a spacing of 3nm centered around 1550nm, are emitted from the same fiber ring laser. A tunable THz frequency component is demonstrated by tuning the FBG inside the laser cavity.**

Index Terms----**Terahertz source, difference frequency, laser, FBG**

1. INTRODUCTION

Terahertz has its electro-magnetic wave frequency range between 0.1THz and 10THz; or wavelength range 3mm ~ 30um. It is located between the electronic and photonic domains. Due to the lack of effective generation and detection methods, this band has been poorly explored [1]. Recent technological breakthrough in the THz radiation is triggering new applications in biology, biomedicine, pharmaceutics, chemical, food, beverage, drugs, security, astronomy, communication and industry *et al* [2, 3]. THz has potential applications in spectroscopy sensing, imaging and communications.

Neither optical nor microwave source techniques can be directly used in the terahertz range. The multidisciplinary characteristics of the THz fields require a deep knowledge of optics and photonics, microwave engineering and semiconductor physics. Till date, the choice for THz signal generation is very limited, especially those sources which can emit high power and tunable wideband THz fields. Development of the THz source is lagging behind the application of THz technology. Various THz sources and its generation techniques have been proposed to generate higher power, and wide band or frequency tunable THz source. We believe that Quantum cascade laser [4, 5] and Difference frequency [6] are the two most potential methods. In order to cut costs and use the present mature technology, we are making use of the 1550nm fiber soliton laser and the DF method to realize a tunable THz source.

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2. EXPERIMENTS AND RESULTS

DF generation is based on the second order nonlinear coefficient in a nonlinear crystal. Unfortunately, the second order nonlinear coefficient of silicon is zero because of its symmetrical structure. Hence, an optical fiber can't be used for DF generation though its length can be very long. A suitable nonlinear crystal has to be found to phase match the pump wavelengths. The DF effect is a nonlinear effect and it also needs a stable phase match between dual IR wavelengths to avoid fluctuations in the THz generation. Keeping stable phase matching is impossible without a phase feedback circuit which is costly. Hence, it is better to use two laser wavelengths from the same laser system as they should have stable phase. As an example, any two modes from a multimode laser or a modelocked laser can be used to achieve this condition.

We designed and fabricated a dual-peak fiber Bragg grating (FBG) which is a sampled FBG with a symmetrical phase shift structure [8], as shown in Fig.1. We place it in a ring fiber soliton laser. Mode locking is achieved and enhanced due to four wave mixing (FWM). After carefully adjusting the polarization, lasing commences at two wavelengths. They have a very stable phase relationship due to the existence of FWM to suppress the homogeneous gain broadening effect. And usually they also have same output polarization, which is highly elliptical based on our tests. We also tried and found that two imposed FBG at the same point also have same function as super-sampled FBG. Fig.2 shows a typical optical reflective spectrum of the FBG, each channel has a bandwidth of 0.1nm. A new FBG tuning mechanism is adopted so that we can shift only one wavelength and change the channel spacing. In this way, we can tune the difference frequency from 0.8nm to 10nm (100GHz- 800GHz).

A half-wavelength waveplate is used to rotate the polarization angle, and then the two wavelengths from

the laser get amplified by a 35dBm short pulse Erbium-doped fiber amplifier (KEOPSYS EDFA) and are launched into a nonlinear semiconductor sample (e.g. InGaAs, GaSe, InAs, InSb or PPLN with different thickness of millimeters). After fine tuning the waveplate and incident beam angle, finally a difference frequency component in the THz range will be generated through DF effect at suitable incident angles for different crystals. A polyethylene lense was used to collect THz components but blocking the IR laser. Then the THz was collected by Erickson PM3 power meter, the maximum reading was 0.1 microwatt which corresponds to a conversion efficiency of about 0.000003%. The reading may not be correct due to its sensitivity limitation of the detector. Another autocorrelator, with a second order harmonic generation (SHG) function, was used to measure dual-wavelength laser output directly. Fig.3 gives a typical result and it shows a 660GHz pulse with a periodicity of 1.5ps which is the exact frequency gap between the two tuned wavelengths, it means the dual-wavelength laser really has signal in Terahertz band. We can achieve a maximum 800GHz output when stretch the FBG before the fiber breaks down.

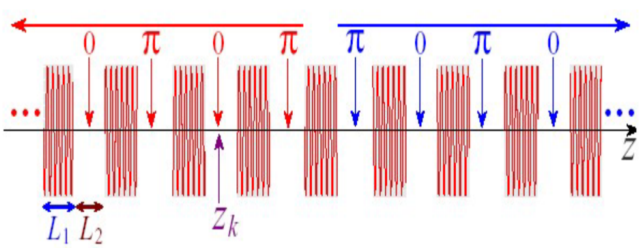

Fig. 1 Phase apodization structure in sampled FBG

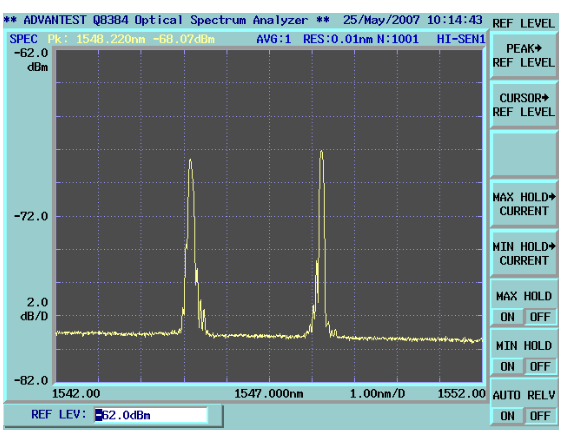

Fig.2 Reflective spectrum of the FBG

We also tried a commercial 90fs femtosecond soliton laser at 1550nm wavelength with repetition rate of 80MHz. And a similar FBG was used to filter out the two wavelengths and then amplify it. The generated THz power was found to be about 10% of the previous method under the same other conditions. This was due to the lower repetition rate of the fs fiber laser.

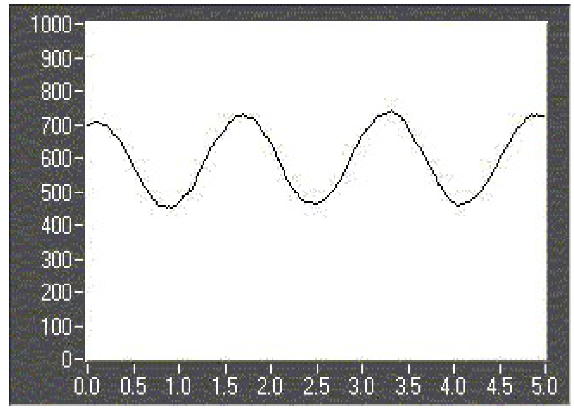

Fig.4 SHG autocorrelation trace of 660GHz

3. CONCLUSIONS

A dual-wavelength fiber laser, with spacing of 3nm around 1550nm, was used to generate THz. A stable phase between the two wavelengths of the laser was achieved due to the DF effect. A tunable THz frequency from 100GHz to 800GHz of 10 nanowatts was demonstrated by tuning the FBG inside the laser cavity.

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