TERAHERTZ GENERATION BY OPTICAL MIXING OF CHIRPED FIBER LASER PULSES

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Since early 1990s a variety of optoelectronic techniques has been developed to generate and detect freely propagating terahertz (THz) frequency signals that have found important applications in far-infrared (FIR) spectroscopy and in THz imaging [1]. Among those techniques, the generation and detection of THz radiation by use of ultrafast photoconductors manufactured from semiconductors with sub-picosecond carrier lifetimes and integrated with wide-band antennas are most often used. In [2] a modification of the existing techniques of generating pulsed THz radiation by photoconductive antennas was proposed by incorporating a simple frequency tuning scheme into it. The scheme relies on the sinusoidal optical modulation achieved by the beating of two linearly chirped broadband optical pulses arriving at the photoconductor with variable delays.

Previous studies to generate THz field by optical mixing relied on using femtosecond solid state [2] or fiber [3] laser sources and introduced the chirp by propagating the pulse through dispersive element. In this work we generated narrowband THz radiation using chirped optical pulses from the picosecond fiber laser system. We used a fiber oscillator which generated 5 ps duration 1053 nm wavelength 0.3 nm bandwidth pulses. After amplification the pulses were propagated through 20 m optical fiber where self phase modulation (SPM) and material dispersion (GVD) stretched the spectrum to ~20 nm and the duration to ~15 ps and introduced strong linear chrip with some nonlinear corrections due to third order dispersion (TOD) and effects of SPM.

Linearly chirped optical pulses emitted by the laser were split into two equal parts and later recombined after being reflected back by dielectric mirrors in a Michelson interferometer based on a non-polarizing beam splitter. One of the mirrors was mounted on a translation stage introducing the temporal delay $\tau$ between the two parts of the optical pulses. Since the pulses were linearly chirped, at each moment of time their frequency content differed by a constant beat frequency $\nu_b$ which was directly proportional to the delay $\tau$. For coherent detection of the generated THz transients, temporally modulated optical pulses from the interferometer output were further divided and used for activation of photoconductive THz emitter and detector components, respectively. Both the emitter and the detector were fabricated from GaAsBi epitaxial layer of a 1.5 μm thickness grown on a semi-insulating GaAs substrate by low-temperature molecular-beam-epitaxy. Coplanar Hertzian dipole antennas with photoconductive gap of 10-15 μm between the Ti-Au metalization lines were deposited on the layers; high resistivity hemispherical Si lenses were attached to the backside of the photoconductive switches. Absolute power of the emitted THz transients was measured in a separate experiment, in which Golay cell was used as a detector.

The main results are presented in Fig. 1 and 2. In short, optically induced THz power spectrum (modeled) is quite flat and extends well beyond 3 THz range. The narrowing effect from nonlinearity of the chirp was found to be small. However measured emitted power spectrum was much narrower and the radiation was not detectible beyond 2.5 THz (Fig.1). This is mainly due to resonant properties of the antenna. From the fitting we found the resonant parameters. The experimentally determined bandwidth of the emitted THz pulses does not change much in the 0.1-1.1 THz range and is ~60 GHz. The modeling results are in very good agreement with the experiments (Fig.2), especially considering zero free parameters in the model. Detailed experimental and modeling results will be presented at the conference.

\begin{figure}[h]
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\includegraphics[width=\textwidth]{fig1.png}
\caption{Measured absolute THz power spectrum and the simulation of induced and emitted THz signals}
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\begin{figure}[h]
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\includegraphics[width=\textwidth]{fig2.png}
\caption{THz signal bandwidth dependence on the central frequency: model and experiments}
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