Generation of high stable wide-range THz radiation for precise frequency measurements

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Abstract— **High stable wide-range radiation sources (frequency synthesizers and generator of harmonics), operating up to 4.9 THz, are presented.**

I. Introduction And Background

PERFORMANCE of high precise measurements requires radiation sources with well defined frequencies and “quartz” parameters of signal. Devices providing these requirements are called frequency synthesizers.

Nowadays frequency measurements in THz frequency range involve application both optical and microwave methods. The most commonly used is optical one with employing of femtosecond lasers and photoconductive switches or nonlinear crystals. As usual for nonlinear processes, generation of high-energy pulses requires phase-matching between the optical and the THz pulses. Difficulty in achieving phase matching of the refractive indices over a broad band of THz frequencies provides a fundamental limitation for the method of optical rectification. Moreover method of optical rectification permits to obtain spectral resolution only of about 1 cm^{-1} with the additional complication of frequency instability. For precise applications (including spectroscopy), it is thus necessary to significantly enhance frequency resolution and frequency stability. This will be especially true if such spectroscopic characteristics of such radiation sources are to meet requirements for measurements at Doppler line resolution ($\sim 10^{-6}$) and frequency measurements with accuracy $\sim 10^{-8}$-10^{-10}.

The microwave approach is based on extension of methods where nonlinear elements (like mixers, multiplier) on Schottky diodes are used. However, direct application of the approach resulted in need of 6 loops of PLL in the first elaborated subTHz frequency synthesizer[5], which operated up to 840 GHz. This made its exploitation very difficult. New opportunities in creation and elaboration of THz synthesizers and harmonic generators appeared with development of devices based on quantum superlattice (SL) diodes[1]. Synthesizers based on BWO lets one obtain generation up to 1.25 THz. Further advancing is very unlikely due to technical problems.

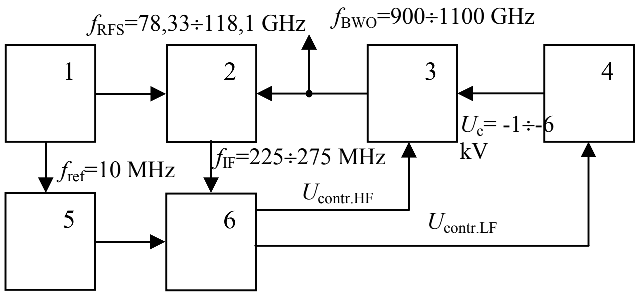
To obtain generation in higher THz range, multiplication of frequency can be used. The Schottky diodes are also widely employed for developing of multipliers, mixers and detectors of THz frequency range[2,3]. However, for a successful operation in the THz region, it is necessary to increase cut off frequency of Schottky diodes that has proven quite difficult due to fundamental restrictions (high inertness of electron pass through an active zone and parasitic capacitances). Furthermore, use of superlattice structures are expected to be more effective for frequency transformation and detection, since the lower values of inertness and parasitic capacitances and presence of negative differential conductivity (up to 1 THz) on the volt-ampere characteristic.

In the present paper, we report, that application of harmonic mixers[4] based on SL allows essentially simplifying the THz synthesizer’s scheme and to improve reliability and stability of BWO work at synchronization mode in all generation range up to 1.25 THz. Multiplication method gives an opportunity to develop a generator of harmonics with very high harmonic’s numbers. Such generator is also presented in the paper.

II. Results

1) Experimental investigations of noise characteristics of harmonic mixers based on SL- diodes[6] are done.

2) We also present various variants of synthesizer, which operate in the ranges of 667 ÷ 857 GHz, 789 ÷ 968 GHz, 882 ÷ 1100 GHz. For the frequency ranges of 667 ÷ 857 GHz and 789 ÷ 968 GHz, the PPL is realized by 37th ÷ 55th harmonics of reference synthesizer with upper frequency up to 20 GHz.



1. Reference frequency synthesizer of 78,33-118,1 GHz frequency range.
2. Quasi-optical tract with harmonic mixer.
3. BWO radiation source based on BWO OB-83
4. High-voltage power supply of BWO
5. Direct digital synthesizer with computer for RS frequency control
6. Synchronizer of BWO frequency.

Fig.1 Block scheme of synthesizer 882÷1100 GHz frequency range

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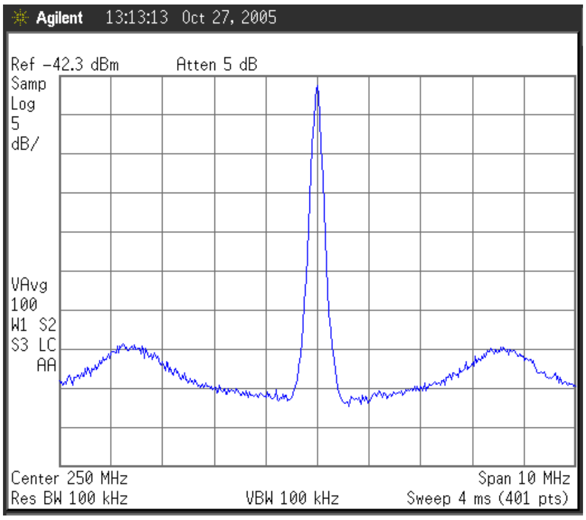

Fig. 2 Spectral line profile of the intermediate frequency signal (f_{IF}=250 MHz) of synthesizer 882 ÷ 1100 GHz.

3) Generator of harmonics based on frequency synthesizer (117-178 GHz) and SL multiplier is elaborated. It operates up to 35th harmonics number, 4.9 THz (see Fig.1).

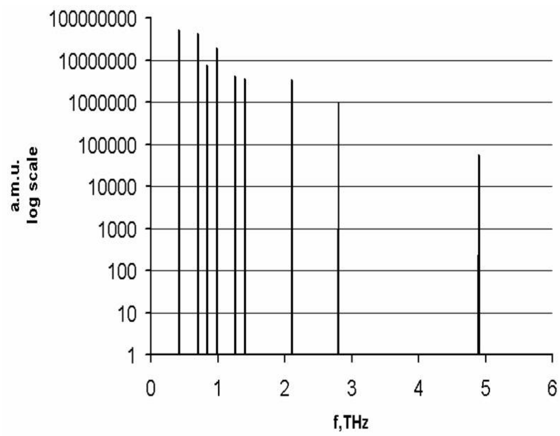

Fig.3 Harmonic's spectral distribution after multiplier

These harmonics can be used for precise measurements. Despite high numbers of harmonics, their power is enough for metrological, spectroscopic applications. It is necessary to know spectral characteristics of harmonics. We have measured the spectrum of 7th harmonics by beating its frequency with synthesizer's frequency 1062 GHz. The results of experiment are shown on Fig.4.

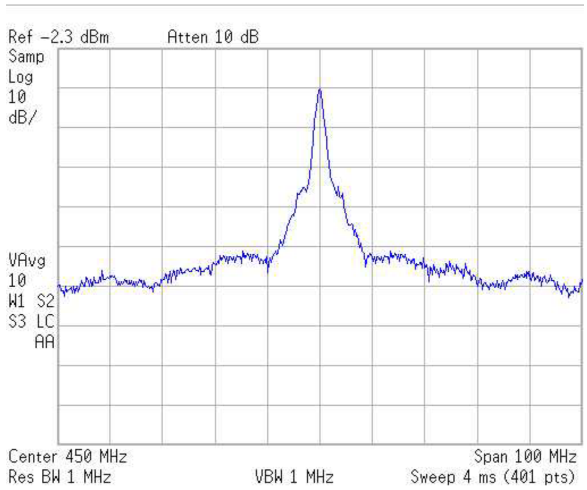

Fig.4 Spectral characteristics of the beat frequency of 7th harmonic and frequency synthesizer.

The presented approach gives an opportunity to elaborate radiation source which frequency could be tuned as by tuning frequency of reference synthesizer and by choosing a number of harmonic.

ACKNOWLEDGMENTS

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