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COMPACT TUNABLE RADIATION SOURCE AT 180–1500 GHz FREQUENCY RANGE

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1 Abstract

This paper is concerned with development of compact continuously tunable over all the submillimeterwave band (180 - 1500 GHz) general purpose radiation source. The source consists of Backward Wave Oscillator (BWO) of the range 180 - 260 GHz or 250 - 375 GHz fixed in a small permanent magnet, followed by specially developed broadband frequency multiplier producing second, third, fourth, fifth and sixth harmonics of BWO fundamental frequency. The conversion losses for all the harmonics are measured. The estimations of output power of the source depending on frequency band are given. The examples of applications are presented in phase lock-in scanning BWO regime.

Keywords: BWO, submillimeterwave, frequency, multiplier.

2 The Source Description

A possibility to have convenient broadband continuously tunable radiation source is major importance for many microwave experiments in millimeter and submillimeter wave range. In the present paper

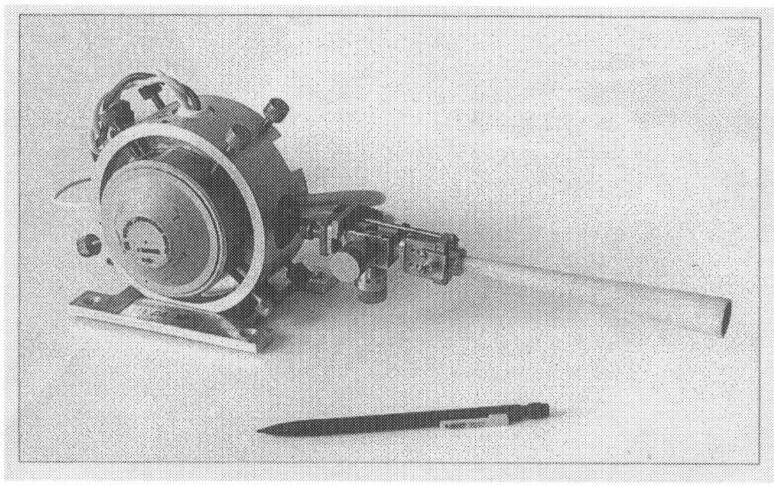

Figure 1: **The general view of radiation source at frequency range 180–1500 GHz.**

we describe compact "BWO + frequency multiplier" radiation source covering continuously 180 – 1500 GHz range developed for general purpose on the base of our experience [1].

The general view of the source is presented in Figure 1.

Two conventional Istok's BWOs of type of [2] are used: OB-24 and OB-30, covering 180-260 GHz and 250-375 GHz bands respectively. But Istok supply BWOs of these types alone i.e. not installed and adjusted in magnets necessary for tube operation [1]. So construction of the compact system with permanent magnets where tubes were fixed was developed in our laboratory. It is analogous to the one used by ISTOK and consists mainly of two Samarium - Cobalt permanent magnet tablets mounted at the both sides of BWO and producing across the tube the 6000 - 7000 Oersteds magnetic field necessary for its operation. Adjustment of electron beam along the slow-wave system of the tube is achieved by movement of the tablets in the plane perpendicular to the beam axis. Once adjusted in proper position, the tube keeps oscillating without necessity of any later additional adjustment. Characteristics of the BWO's are presented in [2] and ISTOK

[1] "Packetized", i.e., installed and adjusted in permanent magnets for immediate operation BWOs are produced by Istok only up to 178 GHz.

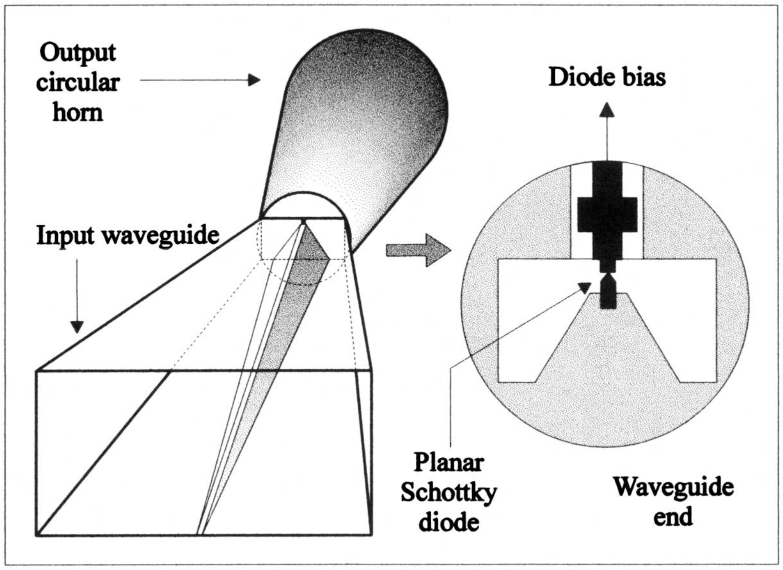

Figure 2: **The construction geometry of radiation frequency multiplier.**

Product Information List. Generally, power of these tubes varies in the range of 10 - 100 mW.

A construction of frequency multiplier is of type of [1] [2]. The scheme of multiplier is given in Fig. 2. The BWO's waveguide output (Russian standard) roughly corresponds to WR-10 standard. The matching multiplier input waveguide is then smoothly narrowed and has an uprising central ridge. The planar Schottky diode as non-linear element is placed at the end of the ridged part of the waveguide. The diode can be biased for harmonics generation optimization. Small angle circular horn antenna serves as the multiplier output. Standard waveguid T-brige with backshorts is placed between the BWO and the multiplier for better matching of the input radiation with the diode

[2]This construction is based on the multiplier - mixer construction first developed by us for Terahertz BWO Phase Lock Loop (PLL) [3]

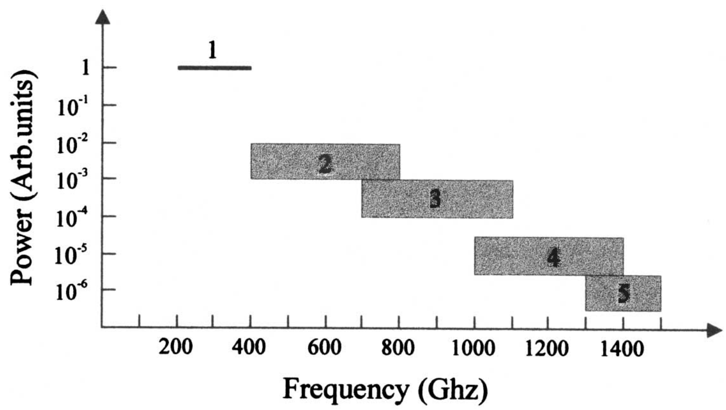

Figure 3: **An estimation of normalized output power of the radiation source with OB-30. Absolute power of the BWO in its working range was 30–70 mW which corresponds to 1 in the plot.**

at the particular frequency selected.

If necessary, for suppression of either the fundamental radiation or any particular harmonic the multiplier can be completed by output radiation quasi-optical frequency selective filters of kind of so called Dichroic Plate filter described, for example, in [4]. In this case the plate filter is fixed at the multiplier horn antenna output by special holder perpendicular to the horn axis. The holder allows to move slightly the plate along the axis so the plate works as a backshort tuner for fundamental radiation. This additionally allows to improve the harmonics generation efficiency but makes the whole system more resonant.

This source was measured and tested in the whole 180 – 1500 GHz range.

3 Conversion Losses Measurements

For obtaining of quantitative characteristics of frequency multiplication for each of separate harmonics (frequency conversion efficiency measurements) the method briefly described earlier [5], [1] and more detailed in [6] was used. In that measurements BWO frequency was phase – locked against harmonic of microwave frequency synthesizer[3], and spectral lines of rarefied gases with well known absorption coefficients were observed in opto-acoustic cell.

The result of measurement of frequency conversion efficiency in the continuous sequence of harmonics produced by the source with OB-24 tube oscillating at about 230 GHz frequency up to the highest microwave range is given in Table 1.

An estimation of the relative range of available output powers of the source with OB-30 tube in the harmonics as compared with power in fundamental for the whole frequency range based on measured frequency conversion efficiency at various harmonics is presented in Fig. 3.

F_f (GHz)	F_h (GHz)	N	FCL (dB)
230.5	230.5	1	0
230.5	461.0	2	-23
230.5	691.5	3	-27
230.5	921.8	4	-33
259.2	1036.9	4	-40
230.4	1152.0	5	-43
253.4	1267.0	5	-52
230.3	1382.0	6	-49
249.5	1496.9	6	-52

Table 1: **Frequency conversion losses (FCL) in the source with OB-24 tube. F_f - fundamental frequency; F_h - frequency of radiation in harmonic; N - harmonic namber.**

4 Examples of the Source Applications

The described source was developed primarily for microwave spectroscopy purposes. So our practical examples include observation of some molecular spectra.

[3]Review of the development of PLL of BWOs up to 1 THz is presented in [7].

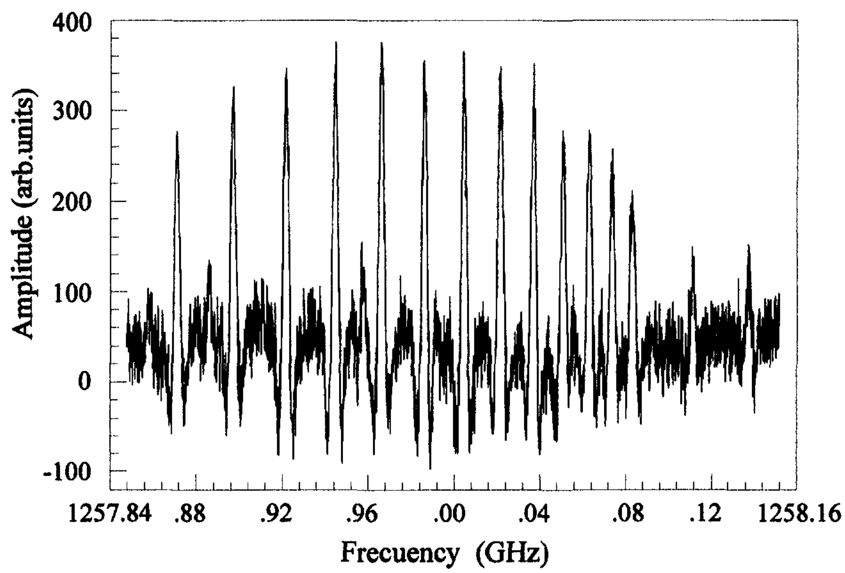

Figure 4: **Example of scan-record of molecular spectrum using the source on 4-th harmonic of OB-30 radiation. $^rQ_4$ – branch of rotational lines of H_2S_2 molecule at 1258 GHz.**

Examples of spectra observed with the use of BWOs are abundant (see, e.g., [3], [8]) where it is shown that with these sources the highest at the moment sensitivity of submillimeter microwave spectrometers has been achieved. Here we demonstrate only (most difficult) higher - frequency examples of the described source usage. The estimation of sensitivity (e.g., signal - to noise) increase with the use of lower harmonics can be easily done with the help of the diagram Fig. 3.

An example of the scan-record of the part of H_2S_2 molecule spectrum is given in Fig. 4 around 1258 GHz. The spectrum was recorded on 4-th harmonic of fundamental radiation of the OB-30 using the source with Cologne microwave spectrometer. The source frequency modulation and the second harmonic of modulation frequency detection were used. Liquid helium cooled QMC bolometer with magnetic tuning was used as receiver of radiation passed through a gas cell. Afore mentioned dichroic plate filter of kind of [4] with cut off frequency 400 GHz was used for fundamental radiation suppression.

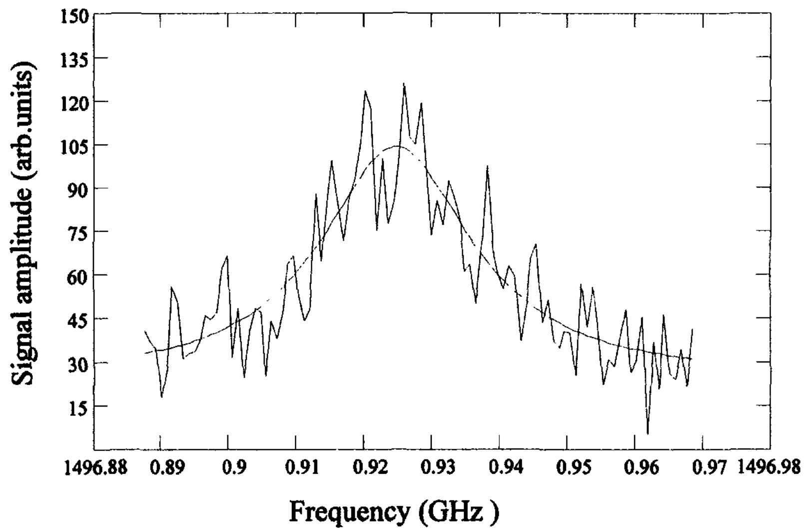

Figure 5: **Record of spectral line of CO molecule corresponding to $J = 13 \leftarrow 12$ rotational transition at 1496 GHz. The line is observed using the source on 6-th harmonic of OB-24 radiation.**

A spectral line of CO molecule near 1497 GHz recorded at highest observed frequency range of the source is presented in Fig. 5. The line was recorded using acoustic (i.e, room temperature thermal) receiver [9] and amplitude modulation of the source radiation.

The compact broadband radiation source described here can serve also for wide range of other than microwave spectroscopy applications, e.g., for microwave measurements, material testing, as a local oscillator in superheterodyne receivers, as a reference source for PLL. The possibility of the use of one device covering of the very broad range of frequencies may make its use preferable in many cases.

5 Acknowledgements

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