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TUNED CAVITY ASSEMBLY FOR HARMONIC GENERATION OF ACOUSTIC
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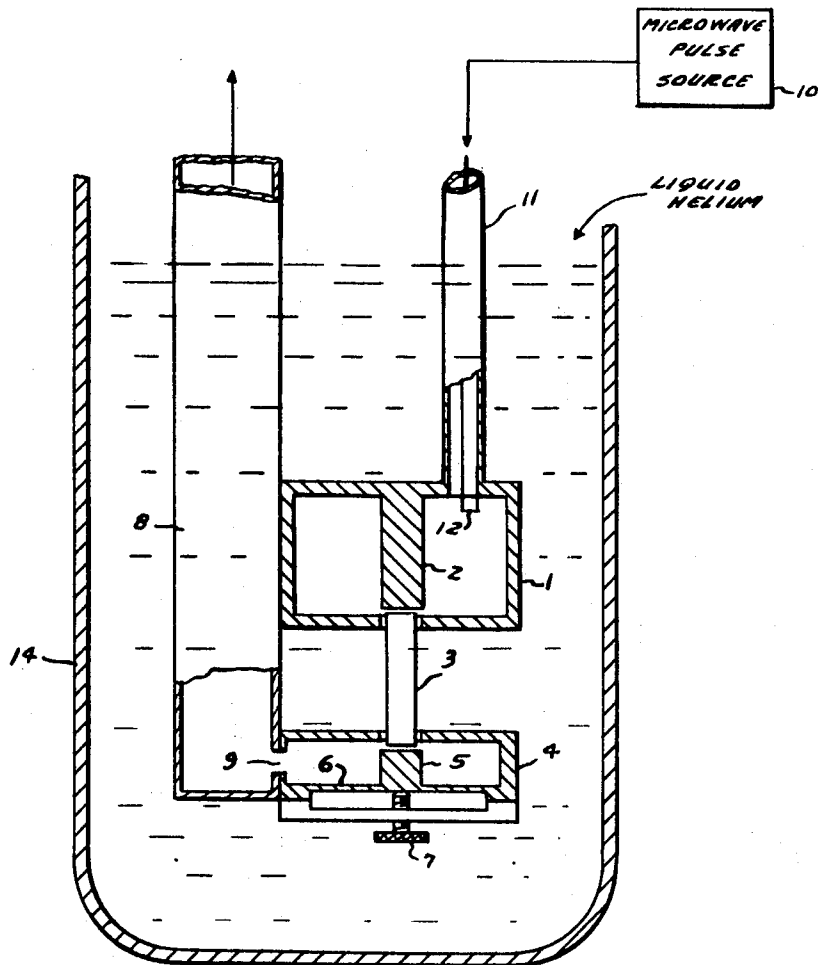


Fig-1

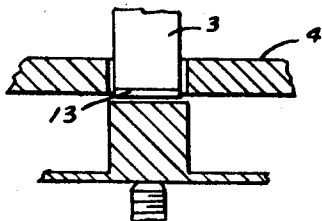


Fig-2

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1

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TUNED CAVITY ASSEMBLY FOR HARMONIC GENERATION OF ACOUSTIC AND ELECTROMAGNETIC WAVES OF GIGACYCLE FREQUENCIES

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1 Claim. (Cl. 321-69)

ABSTRACT OF THE DISCLOSURE

Apparatus for generating electromagnetic waves in the gigahertz frequency range from microwave energy at a lower fundamental frequency comprising a first resonant cavity tuned to the fundamental frequency and energized by the microwave energy, a second resonant cavity tuned to a harmonic of the fundamental frequency and coupled to an output circuit, and a rod of acoustic material having one end at a location of high electric field intensity in one cavity and the other end at a similar location in the other cavity. The acoustic material may be piezoelectric, such as X-cut quartz, or nonpiezoelectric, such as Z-cut quartz. In the latter case, however, a piezoelectric transducer must be attached to the rod end located in the output cavity.

The invention described herein may be manufactured and used by or for the United States Government for governmental purposes without the payment to me of any royalty thereon.

The purpose of this invention is to generate acoustic and electromagnetic waves in the gigacycle frequency range through a process involving the generation of harmonics of acoustic waves produced in a medium by subjecting the medium to an electric field of fundamental frequency. The fundamental acoustic waves may be generated in the medium through operation of the piezoelectric effect in the case of a piezoelectric medium. Thus, it has been found that second and third harmonics may be produced in piezoelectric X-cut, AC-cut and BC-cut quartz, the second harmonic in X-cut quartz being particularly strong. However, second harmonic generation has also been observed in the case of acoustic waves produced in nonpiezoelectric Z-cut quartz and ruby as a result of the stress produced in the medium by the fundamental frequency electric field. This latter acoustic wave generation process applies to all material media and therefore a technique for generating acoustic waves in any material is believed to have been demonstrated for the first time. In the past, acoustic waves have been generated by electromagnetic fields only in piezoelectric or magnetostriction media.

Briefly described, the apparatus for accomplishing the above comprises a pair of microwave resonant cavities, one tuned to the fundamental frequency and the other to the desired harmonic frequency. A rod of the acoustic material, quartz for example, has one end at a location of high electric field intensity in the fundamental frequency cavity and the other end at a location of high electric field intensity in the cavity tuned to the harmonic frequency. The first cavity is energized by radio frequency energy of the fundamental frequency at a relatively high power level. This results in acoustic waves of the fundamental and harmonic frequencies being generated in the rod, which travel down its length to the other end located within the second cavity. If the rod is made of a piezoelectric material these waves produce electric fields of corresponding frequencies within the second cavity due to the piezoelectric effect. If the rod is not made

2

of a piezoelectric material a small piezoelectric transducer is attached to its end to convert the acoustic energy into electrical energy. The second cavity selects the harmonic frequency to which it is tuned and is coupled to an output waveguide for supplying the desired electromagnetic output energy at that frequency.

The invention will be described in more detail with reference to the specific embodiment thereof shown in the accompanying drawings in which

FIG. 1 is a cross-sectional view of the high frequency generator and

FIG. 2 is a modification of FIG. 1 employed when the acoustic material is not piezoelectric.

Referring to FIG. 1, the assembly for generating and detecting the acoustic harmonics comprises a resonant cavity 1 tuned to the fundamental frequency of, for example, 4.5 gc./s. (4.5×10^9 c./s.). This microwave cavity is shown as of the cylindrical reentrant type having a reentrant stem 2 extending from one wall to a position of proximity to the other wall. Maximum electric field intensity in this type cavity exists in the space between the end of the stem and the closely spaced wall. An opening in the wall opposite the end of the stem permits the end of rod 3 to be located in this region of high field intensity. A second cavity 4, of the same type as cavity 1, is made resonant to a harmonic of the fundamental frequency to which cavity 1 is tuned. This, for example, may be the second harmonic frequency or 9 gc./s. As in cavity 1, the other end of rod 3 passes through an opening in the wall of cavity 4 opposite the reentrant stem 5 so that its end is located in the high intensity electric field region between the end of the stem and the wall. One wall of cavity 4 may be a flexible diaphragm 6 to permit precise tuning of the cavity by screw 7. An output rectangular waveguide 8 is coupled to cavity 4 by an iris 9. Rod 3, for example, may be made of piezoelectric X-cut quartz and may have a diameter of about 3.00 mm. and a length of about 1 cm. In the operation of the above described apparatus, cavity 1 may be energized by microsecond pulses of 4.5 gc./s. energy at, for example, 100 watts peak power. This energy is derived from source 10 which is coupled to the cavity by coaxial line 11 and loop 12. A high intensity electric field is developed at the upper end surface of rod 3 where the fundamental and harmonic acoustic waves are generated. The acoustic waves propagate along the rod, with a velocity in the case of X-cut quartz of 5.8×10^5 cm./s., to the other end located in the 9 gc./s. cavity 4. Here the acoustic energy is converted into high frequency electric energy by the piezoelectric effect, the energy at the second harmonic frequency of 9 gc./s. being selected by the critically tuned cavity 4. This energy passes out of cavity 4 through waveguide 8. Measurements have shown that 100 watts of peak power into the 4.5 gc./s. cavity 1 produces 10 mw. of acoustic power at the fundamental frequency of 4.5 gc./s. and 0.1 mw. of acoustic power at the second harmonic frequency of 9 gc./s., the latter due to the nonlinearity of the generating process. With a detection efficiency in the 9 gc./s. cavity of -40 db, the detected electromagnetic power at 9 gc./s. was 0.01 μ w.

It is also possible to excite cavity 1 at 3 gc./s., in which case cavity 4, still tuned to 9 gc./s., selects the third harmonic. In piezoelectric X-cut quartz, the third harmonic acoustic power has been found to be 10^{-7} of the fundamental acoustic power.

The same arrangement described above may be used when rod 3 is made of a nonpiezoelectric material such as Z-cut quartz or ruby. In this case the mechanical stress produced in the material by the electric field itself, or radiation pressure, rather than the stress produced by the

3

piezoelectric effect, generates the acoustic waves. Also, in this case, it is necessary that a piezoelectric transducer be attached to the end of the rod in the cavity tuned to the harmonic in order to convert the acoustic energy into electrical energy for excitation of the cavity. This is illustrated in FIG. 2 where a piezoelectric transducer 13 which may be of the thin film cadmium sulphide type, is shown attached to the end of rod 3. Measurements in this instance, using Z-cut quartz or ruby for rod 3, showed acoustic power in the microwatt region and 10^{-4} μ w. of electromagnetic power at 9 gc./s.

The entire assembly is preferably held at low temperature by submersion in liquid helium in container 14 to reduce the attenuation of the gigacycle acoustic waves below the room temperature value.

For optimum results the ends of rod 3 should be optically flat to one tenth of a wavelength of sodium light and parallel to within 6 seconds of arc. Any suitable mechanical means (not shown) for very slightly bending rod 3 to increase the parallelism of the end faces has been found to be an effective way to maximize the microwave output of the device.

I claim:

1. Apparatus for generating electromagnetic waves at a frequency harmonically related to a fundamental fre-

4

quency, said apparatus comprising: a first resonant cavity tuned to said fundamental frequency; a second resonant cavity tuned to a harmonic of said fundamental frequency; a rod of an acoustic wave supporting nonpiezoelectric material having one end located in a region of high electric field intensity in said first cavity and the other end attached to a piezoelectric transducer which is located in a region of high electric field intensity in said second cavity; a source of high frequency energy of said fundamental frequency coupled to said first cavity; and an output circuit coupled to said second cavity.

References Cited

UNITED STATES PATENTS

3,012,204	12/1961	Dransfeld et al.	330—5
3,012,211	12/1961	Mason	310—8 X
3,037,174	5/1962	Bommel et al.	333—30
3,085,205	4/1963	Sante	328—16
3,254,231	5/1966	Gandhi	330—30 X
3,278,868	10/1966	Kach	333—83

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