Controlling high-power microwave radiation by electromagnetic band gap structures

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Most of the microwave (MW) devices based on electromagnetic band gap structures (EBG) [1] are produced from the materials with constant electrical and magnetic properties and have a fixed structure of the unit cell. It leads to lack of any possibility of tuning. This is a problem for their use in high-speed complex systems of reception/transmission of MW radiation controlled by a computer. To create electrically tunable devices based on EBG structures their passive elements must be replaced by active ones. Plasma can be used as such active element due to its variation in size, density and geometry by changing the discharge current [2, 3]. In [4] the one-dimensional EBG structure in waveguide (23 × 10 mm2) was formed using plasma columns of a glow discharge at low pressure. It was shown, that for formation of the contrast transmission spectrum of the EBG structure the electron density in plasma columns must be higher than 1014 cm–3. At the same time, in order to reduce the attenuation in the pass band plasma column diameters should be 1–3 mm and their number is 3–5. However, using of the discharge tubes filled by gas at low pressure leads to MW breakdown at power higher than 100 W. This may be acceptable for protection and switching devices, for example, but not for direct control and tuning. In this work, we demonstrated the ability to control the propagation of MW radiation at high (about 50 kW) power by EBG structure formed in the waveguide 23 × 10 mm2 by three pulsed discharges in argon at atmospheric pressure.

The electron density in the pulsed discharge plasma was determined from the Stark broadening of the Hα line. The range of variation of the electron density of 1014–1016 cm–3 was determined in the plasma inhomogeneities, which is necessary to change the structure transmission from 0 to
–50 dB in the forbidden band at 8-9 GHz. At that, transmission in the pass band at approximately 10 GHz changes only on about 3 dB. The experimental data are in good agreement with the results of a simulation performed in Ansoft HFSS software.

The transmission spectrum switching rate in dependence of the discharge parameters (the type of gas, flow rate, applied voltage pulse) was investigated. It was shown that the switching time can be about 10 ns and repetition frequency up to 20 kHz, which is determined by the time of pulse discharge plasma decay.

Pulsed discharge in argon at atmospheric pressure with discharge gap of 5 cm was used as a key control element in two-dimensional triangular EBG structure [5]. This structure was irradiated by high power (about 50 kW) MW radiation at frequency 9.15 GHz. If the discharge was as an additional defect, the radiation transmitted through the structure in direction of (45.0 ± 2.5)°, and a transmission disappeared in that direction, when a discharge was as a defect compensator. The transmission changes were about 15 dB in both cases.

The work was supported by grant BRFFR-CNRS F15F-004.

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