260 GHz CW gyrotron heating substitution with second-long laser pulses in waveguide semiconductor switches

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Sub-Terahertz waveguide semiconductor switches driven by laser emission [1] are used to cut a continuous-working (CW) microwave emission to series of wave packets [2, 3]. The main advantage of the switches is low distortion to the phases of the packets' high frequency fillings at the output [4]. The phases are linked to each other since the microwave input emission is coherent, e.g. a gyrotron in a phase stabilization regime. Recent studies achieved nanosecond level of switching performance [5] for 260 GHz frequency band and 532 nm laser emission [6] using a semiconductor plate of plain gallium arsenide.

Up to now, the switches have been tested with a commutated microwave power of up to 50 mW, limited by the backward-wave oscillator (BWO) test source. The maximum possible power is limited by a WR3 waveguide standard safety value; it is about 20 W (about two times lower than the breakdown value). An obvious solution of increasing smoothly the power level from 50 mW to 20 W using modern gyrotrons faces the problem of measuring errors. Since the rated power for the gyrotrons and their measuring calorimeters is about 1 kW, using them at 20 W produces measurement errors of about 100%, and worse than that, for lower powers. There are no precision commercial measurement devices for frequencies around 300 GHz for the moment.

The maximum heating zone is obviously located on the semiconductor plate, not on the metallic switch housing. There are two sources of heating, specifically, laser energy and Joule heating by the commutated microwave signal. So, for the temperature T within the semiconductor we can write:

$$\frac{\partial T}{\partial t} = B\Delta T + J(\vec{r},t) + L(\vec{r},t)\,, \qquad (1)$$

where t is the time, $\vec{r}$ is the position, B = 0.31 cm^2/s is the thermal diffusivity for GaAs, Δ is the Laplace operator, $J(\vec{r},t)$ is the Joule heating, and $L(\vec{r},t)$ is the laser heating distribution. However, laser-power precision measurement devices are easily available. So, we can approximate the Joule microwave heating by substituting it with the appropriate laser heating. For infrared lasers [7], the function $L(\vec{r},t)$ from (1) is like $J(\vec{r},t)$, their maxima are at the surface, and they both decay inside the semiconductor. Knowing a part of the dissipated laser power at the semiconductor and another part is reflected, we can convert it to an effective microwave commutated power using the power transmission measurement for a typical switch.

The experiments [7] show the average microwave power transmission coefficient is about –0.4 dB for a wide frequency region. So, the microwave power insertion loss is about 9%. Then, assuming that all the microwave loss is dissipated inside the semiconductor plate, we can say that if the switch withstands a certain laser power, it should withstand a microwave power being 8 times as high.

References

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