Microwave generator based on the Josephson Junction

LABORATORY OF TOPOLOGICAL QUANTUM PHENOMENA IN SUPERCONDUCTING SYSTEMS

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Introduction

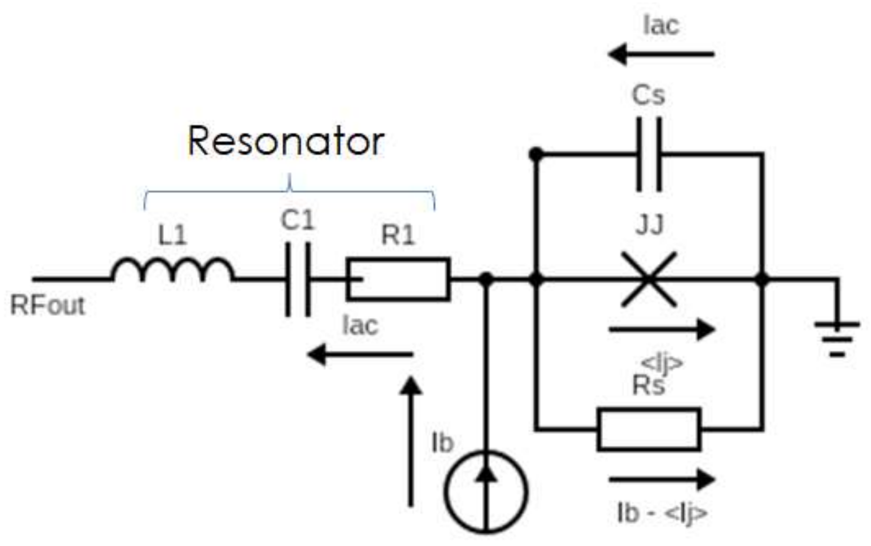

fig 1. An equivalent generator circuit proposed in [1]. The generator consists of a Josephson junction, a microwave resonator, a shunt capacitance and a resistance

Physical systems used for quantum computing operating in the microwave range require advanced control electronics, and the use of integrated components operating at the temperature of quantum devices is potentially beneficial. In [1], a generator operating at a temperature of 20 mK at a frequency corresponding to the control of qubits was demonstrated. However, the manufacturing technology of this device is quite time-consuming.

In this paper, we consider a generator consisting of a Josephson junction, a microwave resonator, a shunt capacitance and a resistance. The aim of the work is to determine the range of generator parameters in which stable generation is possible by numerical solution of the system dynamics equations, the manufacture of individual generator elements, as well as the search for its optimal parameters using modeling taking into account the obtained generator elements.

Results

System modeling:

- As a criterion for the appearance of generation, the condition of the negative part of the actual impedance value is used when the alternating voltage drops at the Josephson junction [2].
- The resulting generation power is spent on dissipation and payload. The total loss power can be described in terms of resistance, which in turn is related to the Q-factor of the resonator. This requirement makes the condition above more stringent.
- The impedance is calculated as the ratio of the first Fourier harmonic of the voltage at the resonator frequency [3].
- In the case of considering a generator that uses SNS without a shunt capacity ($\beta = 0$) stable generation is not observed. The result of modeling such a generator is shown in **fig. 2**.
- The presence of even a small capacity in the system ensures the appearance of generation. (**fig. 3**). Generation is observed when: $\beta > 0.1, W > 0.2$

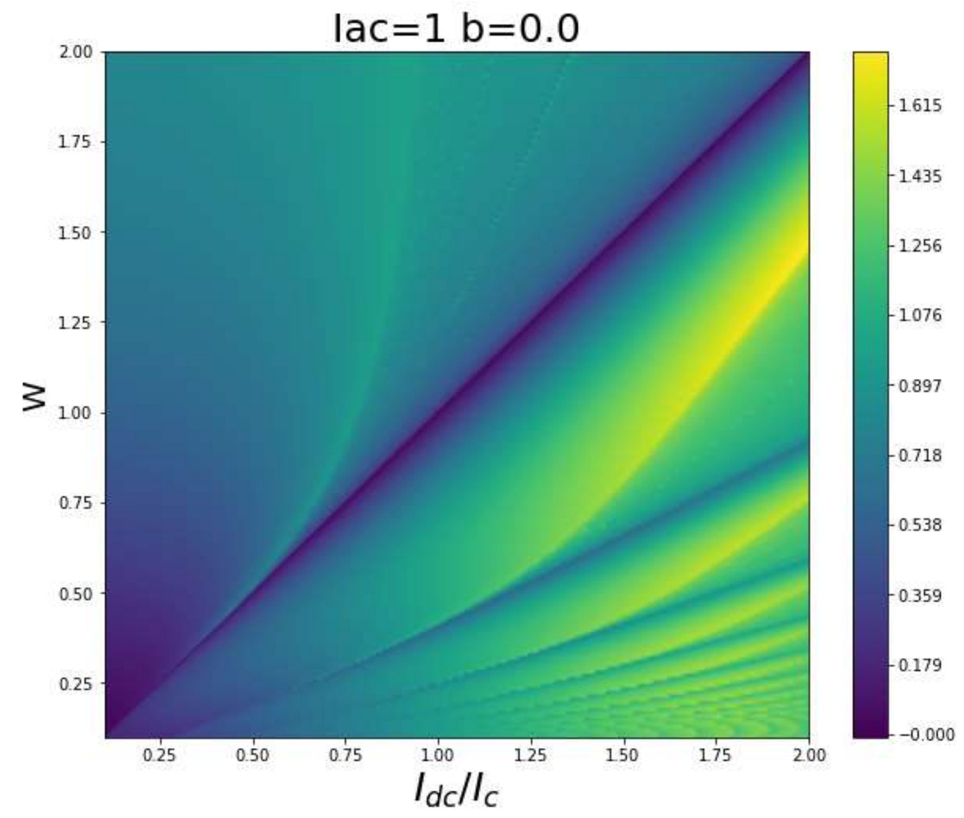

Fig 2. The dependence of the normalized impedance (indicated by color) on the normalized pump current and the normalized frequency at a fixed AC amplitude in the absence of capacitance in the system

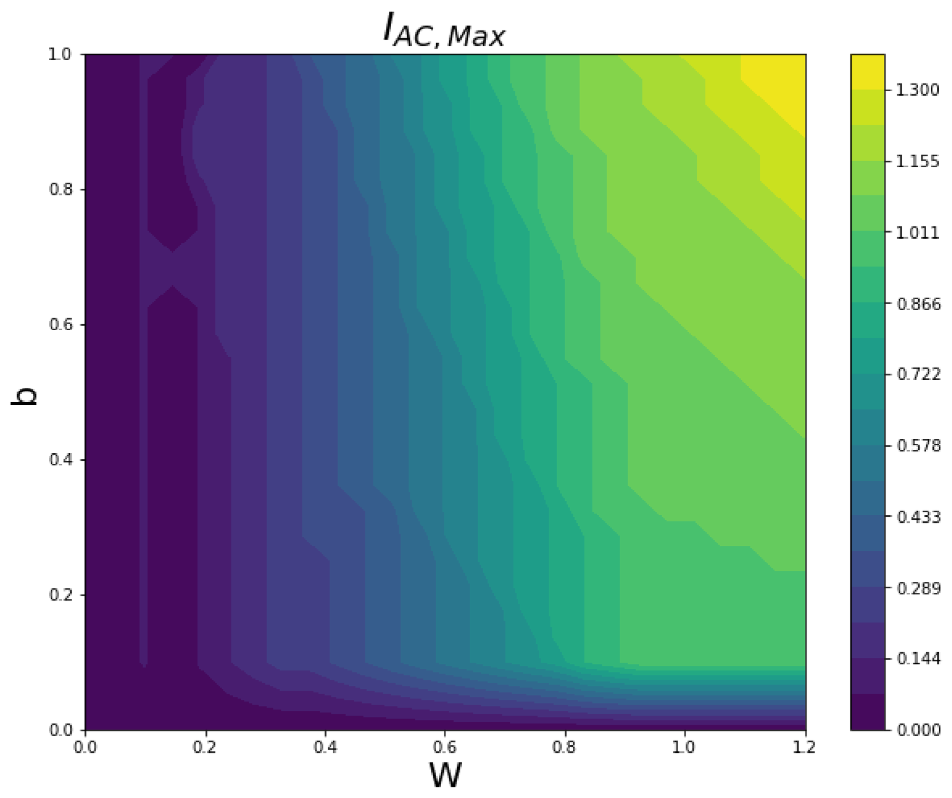

Fig 3. Dependence of the maximum normalized generated AC amplitude (indicated by color) on small system parameters

Manufacturing of individual generator elements::

- As a shunt resistance, a strip of copper is used, the length of which can be changed during the manufacture of the chip, thereby selecting the desired resistance.
- the capacitance is a planar capacitor shown on **fig. 4**. The resulting capacitance of such a capacitor with the occupied area 1 mm 2 was: $C = 40\,pF$.
- Using the dependence of the critical current on temperature (**fig. 5**) the operating point of the generator can also be adjusted.
- A coplanar resonator is used as a resonator : $Q_l \approx 25000$

	f (GHz)	C (pF)	Q_l	I_c (μA)	R_t (Ohm)	P_{out} (pW)	β	W
Result	8	40	20000	25	2	15	11.1	0.35
Article [1]	5.3	200	6000	10	1	25	5.83	1.08

Table 1. Comparison of the obtained generator characteristics with the results [1]

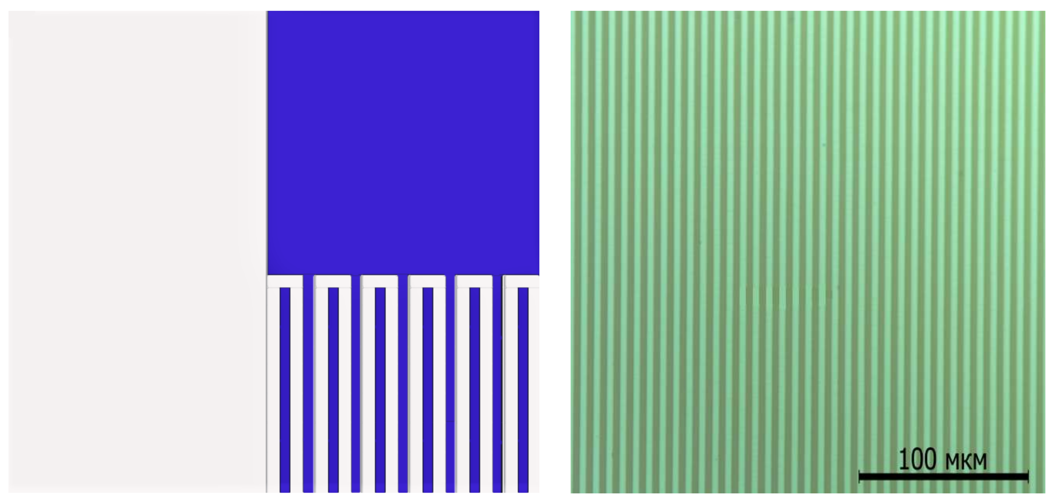

Fig 5. Left: design of a planar capacitor; right: photo of the resulting sample

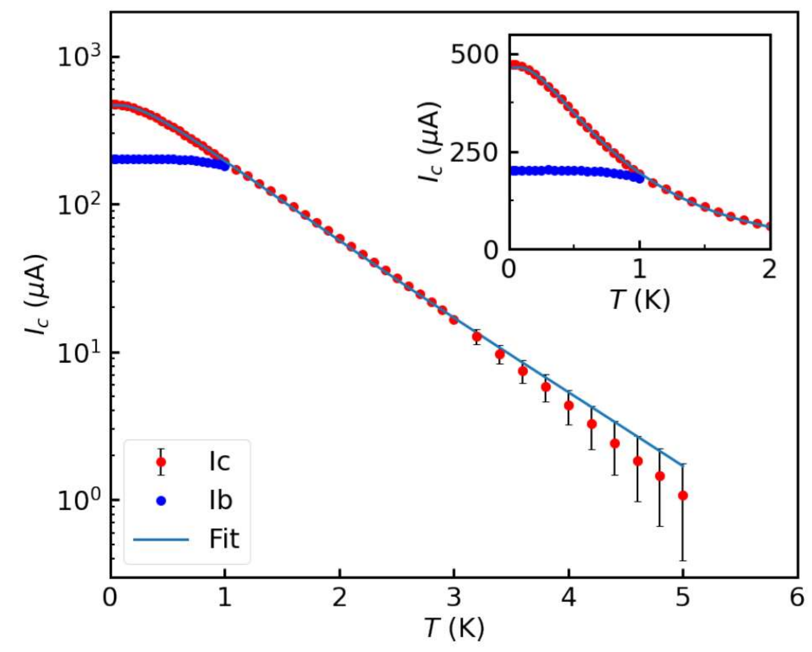

Fig 6. Dependence of the critical current SNS on temperature [4]

Modeling + manufactured elements :

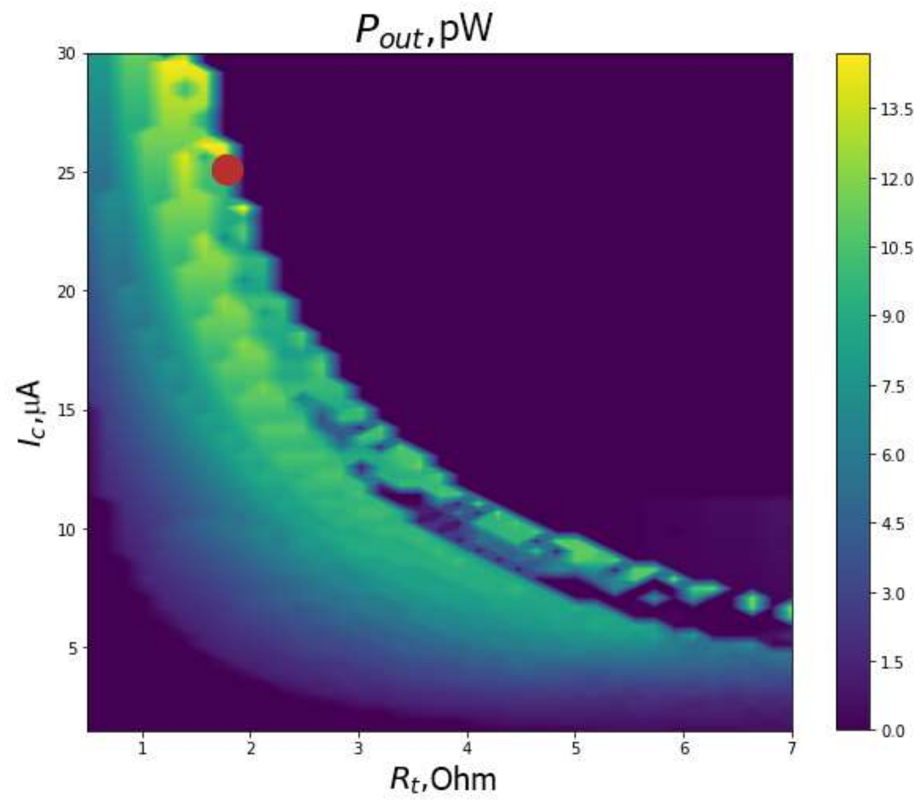

Fig 7. The dependence of the AC generation power (indicated by color) on the actual parameters of the system. The maximum possible power is highlighted with a red dot

Conclusion

This work is devoted to the development of a new design and technology of the Josephson microwave generator. In the course of this work, numerical simulation of the dynamics of the Josephson generator was carried out and a program for calculating the generation power was written. Generator elements were manufactured and measured: planar capacitors, Josephson SNS junctions and normal resistance. The experimentally obtained characteristics of the elements formed the basis for the search for optimal parameters for the generator. A significant and new result of this work is the fact that these values can be obtained using planar technology, which will simplify the manufacture of the generator compared to the use of multilayer structures.

References

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