NEWSLETTER

of the International Consortium "Development of High-Power Terahertz Science & Technology"

June 2021 № 18

CONTENT

EDITORIAL: HOW TO CONTRIBUTE TO THE NEWSLETTER

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- Research highlights (annotations) presenting the projects pursued by the members of the Consortium.
- Short regular and invited papers.
- Proposals for collaborative research work.
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Experimental Demonstration of Gyrotron Frequency Stabilization by Resonant Reflection

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Currently, gyrotrons are among the most popular and promising sources of microwave radiation for various applications such as plasma heating and diagnostics, spectroscopy of various media, and technological processes. Therefore, their spectral characteristics are of great interest to the community, and the gyrotron frequency tuning and stabilization are actively investigated. Many studies considered active frequency manipulation by variation of the electron beam parameters, as well as phase locking by the external signal and changing the spectral characteristics of the radiation (spectrum control), in particular, frequency stabilization by the wave reflected from the nonresonant load. Each of the methods has its advantages and limitations. The active frequency manipulation provides the best stability and control but has speed limitations. The phase-locking requires the external stabilized source with the power of several percent of the gyrotron, and the use of reflection from nonresonant load requires a long delay line.

The method of frequency stabilization and spectrum control using the high-Q loads is free of the listed restrictions. This method is well known and is used in numerous applications, such as the feeding of microtron and linear accelerators by magnetrons in microwave electronics or stabilization of laser frequency. The theory of gyrotron frequency stabilization by the external high-resonant load was developed in [1-3]. This report presents experimental results and simulation of frequency stabilization of gyrotron by the signal reflected from the resonant (high-Q) load.

The influence of the narrow-band signal reflected from the resonator with high quality factor Q can be considered as the frequency locking by an external quasi-monochromatic signal. The radiation frequency of the gyrotron with a variation of its parameters, for example, the magnetic field, can be kept in a narrow frequency band of the external resonator f_{res}/Q_{res}. For this, the phase of the reflected wave must be optimal, and the magnetic field must vary in such an interval, that the corresponding radiation frequency of the free-running gyrotron remains close to the frequency of the external resonator f_{res} within a locking bandwidth $R_0\, f_{res}/Q_{dif}$. Here Q_{res} is the quality factor of the resonant reflector, Q_{dif} is diffraction Q-factor of the gyrotron cavity, R0 is maximal value of the reflection coefficient. Dependence of the reflection coefficient (amplitude-wise) on the frequency for the resonant reflector is $R = R_0/(1+i\xi)$, where $\xi = 2Q_{res}\left(f_{rad} - f_{res}\right)/f_{res}$, f_{rad} being the gyrotron radiation frequency. Using the theory of the gyrotron with resonant reflections, one can obtain the relationship between magnetic field B and the gyrotron radiation frequency:

$$B = \overline{B} + \frac{f_{rad} - f_{rad\,0}\left(\overline{B}\right) + f_{res}K\left(\cos\psi - \xi\sin\psi\right)/G}{\left(f_{rad\,0}\right)'_B},$$

where $f_{rad0}\left(\overline{B}\right)$ is the free-running gyrotron radiation frequency corresponding to the value of the magnetic field $\overline{B}$ in the absence of an external resonator; $\left(f_{rad0}\right)'_B \approx const$ is the derivative of the free-running radiation frequency over B within the interval of the magnetic field, where $f_{rad0}\left(B\right)$ is close to f_{res}, $G = Q_{res}\left(1+\xi^2\right)$. $K = \sqrt{1+q^2}\,R_0\,Q_{res}/Q_{dif}$ is the stabilization coefficient, $\psi = 2\pi f_{res}t_d + arctg\left(1/q\right)$ is the phase of the reflected signal, where t_d is the delay time and $q = \mathrm{Re}\left[\chi'_A\right]/\mathrm{Im}\left[\chi'_A\right]$; χ'_A is the derivative of the electron beam complex susceptibility over field amplitude for free-running gyrotron. Within the magnetic field interval, where $f_{rad0}(B)$ is close to f_{res}, we can consider the q and K constant.

This expression was derived using a single-mode model of the gyrotron with the fixed field stricture; the electron beam was considered ideal (i.e., without velocity and position spread). For the considered low-frequency setup, the frequency separation of the neighbor modes is sufficient, and the Q factor of the gyrotron resonator is relatively big, which allows us to make the estimations using the simple approach. Using the real gyrotron and reflector parameters, we can get the dependence of the frequency on the magnetic field. An example of such a curve for the parameters of the experiment (K = 4 and favorable ψ = 3π/2) is presented in Fig. 1.

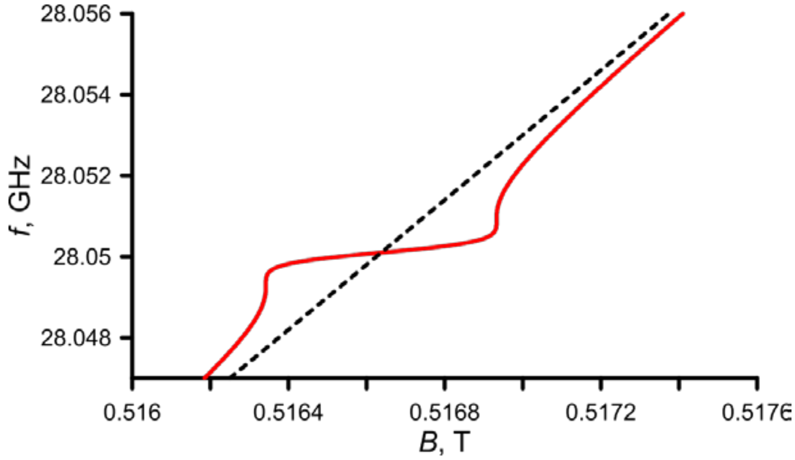

Fig. 1. Theoretical dependence of the gyrotron frequency on the magnetic field for the phase of the reflected signal ψ = 3π/2 and stabilization coefficient K = 4, which corresponds to the parameters of the experiment. The dashed line represents the free-running gyrotron; the solid line is the gyrotron with the resonance reflector.

A gyrotron with an output frequency of 28 GHz and power up to 15 kW, operating at the second cyclotron harmonic at the TE02 mode, was used for theoretical estimations as well as experimental tests. The gyrotron has a cylindrical cavity with linear input and output tapers with a total quality factor Q_0 of ~3400. The gyrotron has a direct output at the TE0,2 mode in a cylindrical waveguide with a diameter of 32 mm.

The resonant reflections were provided by the quasi-optical resonator with two spherical mirrors. The mirror diameter was 120 mm, curvature radius - 390 mm, the distance between the mirrors was about 240 mm, and was fine-tuned by a micrometric adjustment screw. Since the gyrotron has the direct output of the radiation, the set of waveguide converters from TE0,2 mode of the gyrotron resonator to the Gaussian beam (TE0,2 – TE0,1 – TE1,1 – TEM0,0) was installed after the output window of the gyrotron. The gyrotron and resonator's coupling was done using the polyethylene terephthalate (PET) film with 180 μm thickness, installed at the 45-degree angle to the wave propagation direction (Fig. 2). The resulting measured quality factor of the quasi-optical resonator was about 30 000, and the power reflection coefficient was $|R|^2 = 10\%$. The scheme of the experiment is presented in Fig. 2; the measured reflection coefficient for different mirror separations is shown in Fig. 3.

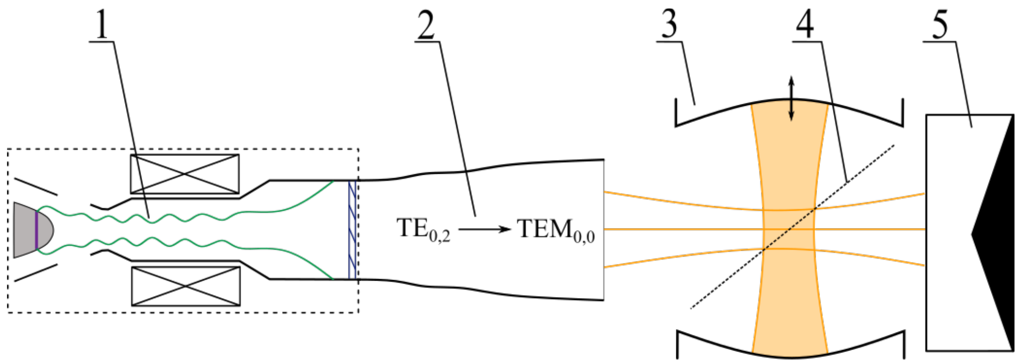

Fig. 2. The layout of the experiment: 1 – gyrotron; 2 – waveguide mode converter; 3 – quasi-optical resonator; 4 – PET film; 5 – dummy load.

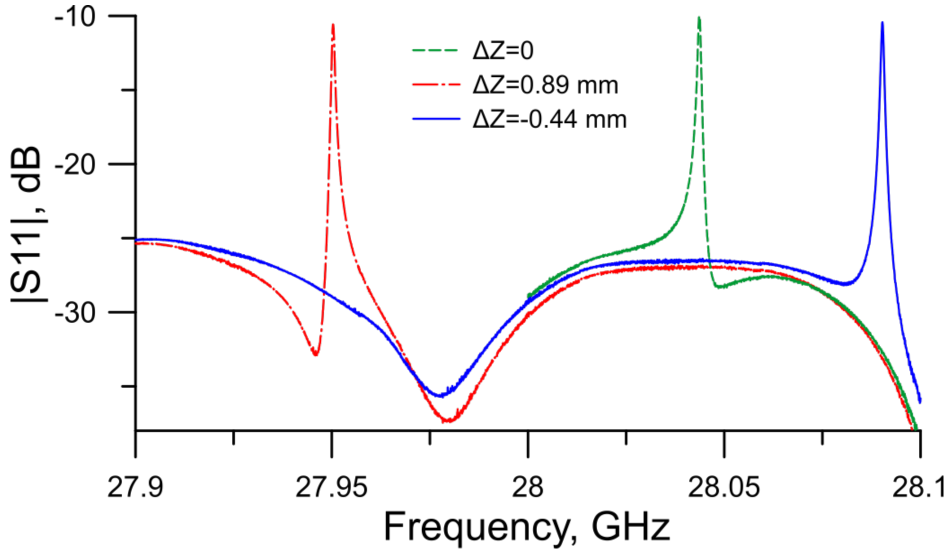

Fig. 3. Measured frequency dependence of the reflection coefficient |S11| of the quasi-optical resonator for different mirror separations. It is important that tuning of the resonant frequency within a gyrotron operation band (27.95-28.1 GHz) does not change the maximal reflection coefficient.

In order to limit the heating of the PET film in the quasi-optical resonator, the gyrotron was operated in the low-power regime, with accelerating voltage U0 = 16 kV, beam current 0.45 A, and maximum output power 1.8 kW. The frequency of the resonator was tuned to the value inside the gyrotron frequency tuning band by adjustment of the mirror separation, the exact resonant frequency was f_{res} = 28.0501 GHz. The spectral characteristics of the gyrotron radiation were measured using an Agilent N9010A spectrum analyzer. The gyrotron was turned on at a high magnetic field in the region of soft TE0,2 mode excitation, and then the magnetic field B was decreased in small steps. For each magnetic field, the gyrotron radiation spectrum was recorded and then combined to present the dependence of the radiation frequency and spectrum width on the magnetic field. Obtained combined spectra are presented in Fig 4 for the free-running gyrotron and the gyrotron with the quasi-optical resonator in the output transmission line.

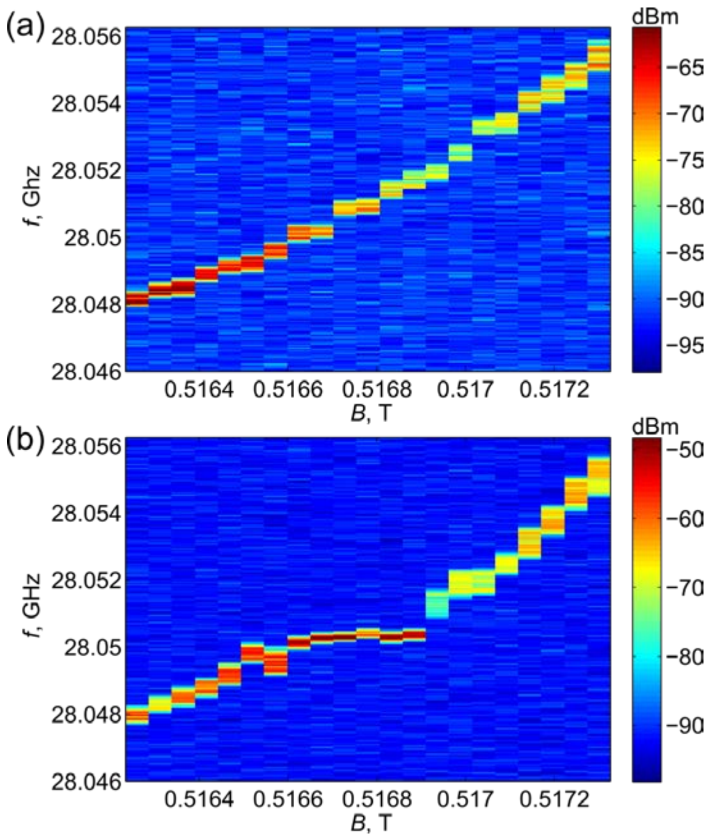

Fig. 4. Combined spectra of gyrotron radiation for a set of magnetic fields for the free-running gyrotron (a) and the gyrotron with a resonant reflector (b).

Obtained data clearly demonstrates the effect of frequency stabilization by reflections of the gyrotron output signal from a resonant reflector. When the gyrotron frequency lies within the external resonator's frequency-locking band, and the reflected signal phase is optimized, the gyrotron frequency's sensitivity to technical parameters' variations is significantly reduced. The df/dB is reduced by approximately ten times, from 7 GHz/T to 0.8 GHz/T (Fig. 4), and the sensitivity to the variation of the accelerating voltage df/dU0 is reduced from 3.5 MHz/kV to 0.6 MHz/kV (which is demonstrated by the spectrum width). A comparison of the spectrums at the same magnetic field for the free-running gyrotron and the gyrotron with the resonant reflector is presented in Fig. 5.

The possibility of frequency stabilization in the locking band of the resonant reflector, with reducing the sensitivity both to the magnetic field and accelerating voltage variation up to ten times, has been demonstrated. Obtained experimental data is in agreement with theoretical predictions.

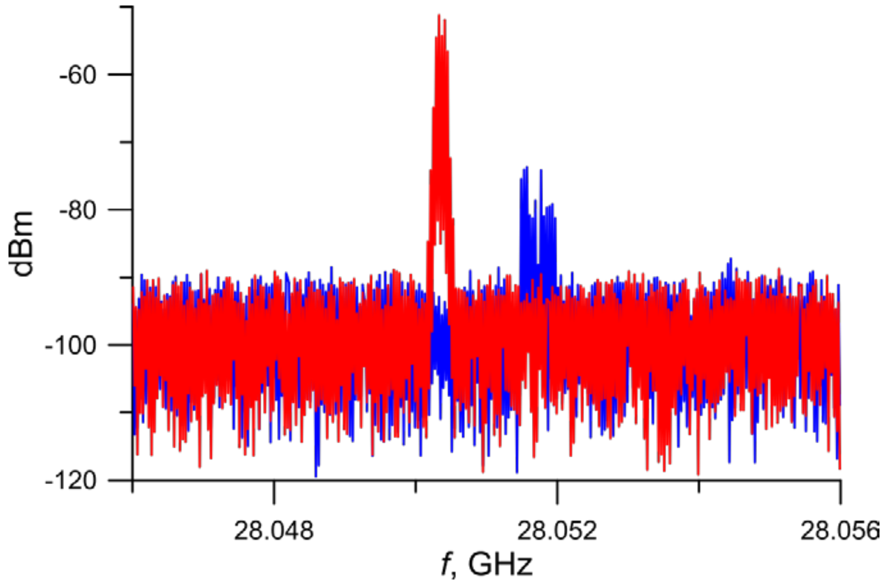

Fig. 5. The spectrum of the free-running gyrotron (blue) and the gyrotron with the resonant reflector (red) for the case of operation within the locking band (B = 0.5167 T).

To advance the considered method of frequency stabilization by reflections from the resonant load to the high power gyrotrons, it is possible to use, for example, the travelling-wave resonator with the corrugated mirror as the coupling element. It is also possible to use the same scheme with the quasi-optical resonator, but with the water-cooled diamond disc as the coupler (similar to the output windows of the MW-class gyrotrons).

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For more detail, please access the original publication:

A.P. Fokin, A.A. Bogdashov, Yu.V. Novozhilova, V.L. Bakunin, V.V. Parshin, M.Yu. Glyavin, "Experimental Demonstration of Gyrotron Frequency Stabilization by Resonant Reflection," IEEE Electron Device Letters, (2021) DOI: 10.1109/LED.2021.3083641.

Automodulation instability in gyrotrons operating at the second cyclotron harmonic

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I. Introduction

Gyrotron operation at cyclotron harmonics in existing cryomagnets is very attractive because it allows increasing the operating frequency proportionally to the harmonic number $n_s > 1$. As any source of high-power electromagnetic (EM) radiation driven by an electron beam, high-power gyrotrons operate in high-order modes of microwave circuits serving as an interaction space. Therefore, as a rule, in addition to the desired mode, an electron beam can resonantly interact with some parasitic modes having the frequencies close to the electron cyclotron frequency or its harmonics. Competition between such modes was, first, studied for the case of pair-wise interaction, when only one parasitic mode competes with the desired one. Then, the demands for further increasing the gyrotron power resulted in operating in higher-order modes where the mode spectrum is denser. In general, the choice of operating modes was always a challenge. Initially, in the 1960s-1970s, the symmetric $TE_{m,p}$-modes with azimuthal indices $m = 0$ were used in gyrotrons operating at the fundamental cyclotron resonance. Such modes were especially attractive for high-frequency (sub-terahertz and terahertz) gyrotrons because they have lower ohmic losses than azimuthally rotating ones. However, later this development was stopped because of severe competition between the $TE_{0,p}$- modes and the $TE_{2,p}$- modes with close frequencies, with the latter being stronger coupled to electron beams. As a result, the gyrotron development was switched toward operating in azimuthally rotating $TE_{m,p}$-modes with azimuthal indices $m \neq 0$.

Recently, it was shown [1] that in harmonic gyrotrons operating in symmetric modes with azimuthal indices $m = 0$, the electron beam coupling to the competing modes with m=2 can be much weaker. So, a stable operation at cyclotron harmonics can be realized even in the case of high-order symmetric modes. This sort of operation is very attractive because it allows the development of high-power gyrotrons with an acceptable level of ohmic loss density at higher frequencies (sub-terahertz and THz frequency range).

In [1], it was shown that a high-order symmetric mode operating at the second cyclotron harmonic could be selectively excited in spite of the presence of parasitic modes at the fundamental in the resonator spectrum. However, the stability was analyzed in [1] for the pair-wise interaction, i.e., when only one parasitic mode at the fundamental has a frequency close to one half of the operating mode's frequency. The multimode dynamics is frequently investigated in powerful gyrotrons operating in high-order modes at the fundamental, while the number of studies of harmonic gyrotrons is relatively small.

In general, for gyrotrons operating at harmonics, the automodulation (or sideband) instability is caused by the parametric interaction between the desired mode at the second harmonic (either rotating with $m \neq 0$ or symmetric with $m = 0$), and a pair of parasitic waves at the fundamental is very important. The conditions for the parametric coupling of such modes can be formulated as conditions for the frequencies and azimuthal indices of these modes as

$$\left|\omega_1 + \omega_3 - \omega_2\right| \leq \frac{\omega}{Q}, \qquad (1)$$

$$m_1 + m_3 = m_2. \qquad (2)$$

In (1)-(2), the index '2' designates the desired mode at the second cyclotron harmonic, and '1' and '3' designate two modes at the fundamental. Equations (1) and (2) are analogous to the photon energy and angular momentum conservation law in nonlinear optics. From Eq. (2), it follows that in the case of a *symmetric* harmonic mode ($m_2 = 0$) it should be $m_3 = -m_1$. This condition means that the pair of parasitic modes can be formed by a single $TE_{m,p}$-mode with two polarizations, i.e., by two waves with the same absolute value of the azimuthal index, which are co- and counter-rotating with electrons azimuthally. When the condition (1) is not valid, we should expect a more straightforward case of pair-wise interaction, in which the phase difference between the modes with well-separated frequencies varies much faster than the mode amplitudes do. Therefore, we can average equations for the mode amplitudes over the fast beating of the phase difference of these three modes. As a result, the equations for mode amplitudes become independent on the phase relations.

Our present study aims to analyze the role, which the pair of parasitic modes at the fundamental can play in the stability of oscillations in second harmonic gyrotrons. Theoretical estimation and numerical modeling are based on the well-known model with a fixed longitudinal mode structure [2].

Some possible detunings of operation (second harmonic) and parasitic (fundamental one) modes are illustrated by Fig. 1.

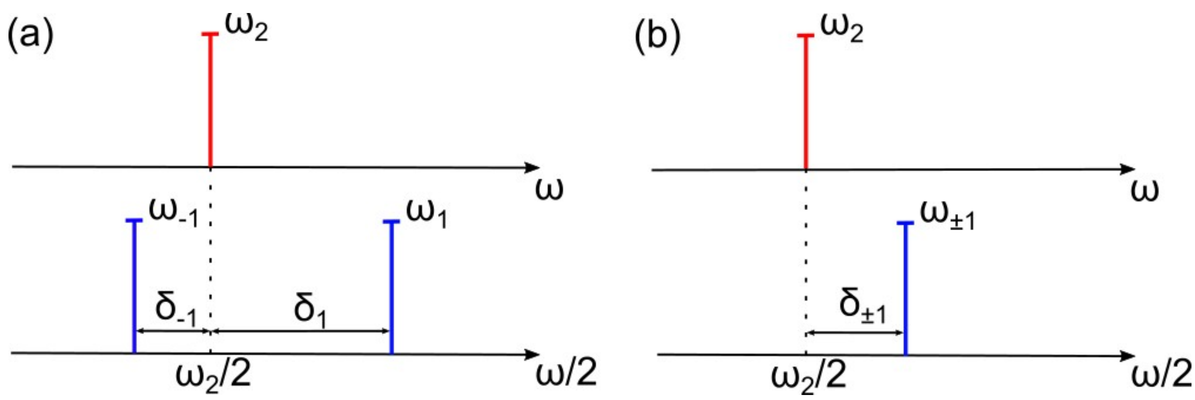

Fig. 1 Operating mode at the second cyclotron harmonic (ω_2) and the pair of modes at the fundamental for the case of non-symmetric (a) and symmetric (b) operating mode.

To further investigate the conditions for automodulation instability in a gyrotron operating at the second cyclotron harmonic, we performed a numerical simulation of the multimode processes in the cold-cavity approximation (i.e. ignoring effect of an electron beam on the axial structure of the resonator field). For minimizing the number of parameters characterizing the gyrotron operation, we assumed that the axial structure of the resonator field could be described by the Gaussian distribution $f(\varsigma) = \exp\left\{-\left(2\varsigma / \varsigma_{out}\right)^2\right\}$.

Prior to analyzing stability of single-mode oscillations at the second harmonic, we should describe the stationary operation in this mode. To achieve the maximum efficiency of the operating mode at the second harmonic, the normalized length of the interaction space was chosen equal to $\varsigma_{out} = 7.5$. In Fig. 2, the lines of equal orbital efficiencies are shown in the plane of the beam current parameter $\hat{I}_2 = I_2 Q_2$ and the cyclotron resonance mismatch; the dashed line represents the starting current. These results show that the maximum efficiency corresponds to the normalized current parameter close to $\hat{I}_2 = 0.5$ and the optimal value of the cyclotron mismatch of $\Delta = 0.57$. This optimal point lies in the region of hard self-excitation. For getting there, a gyrotron should be driven by a proper start-up scenario, which implies either tuning of the guiding magnetic field or the variation of the beam and mod-anode voltages during the voltage rise.

Next, we use the electron motion calculated at the first step to solve the perturbation equations and then define the region of instability in the parameter space, and the stability criteria. When the normalized parameters of the operating mode are fixed, it is necessary to determine the region of its instability in the plane of detunings of two parasitic modes at the fundamental. In our simulations, the quality factors of both sidebands were considered equal, and their ratio to the Q-factor of the operating mode: $Q_{\pm 1} = Q_2 / 4$. The coupling coefficients $G_{\pm 1} / G_2 = 4$, which give us the normalized currents for the satellites $I_{\pm 1} = I_2 / \beta_\perp^2$. For the gyrotron with the operating mode Q-factor $Q_2 = 1000$, accelerating voltage 100 kV, and beam pitch-factor 1.2, the limits for the mode mismatches are given as follows: $\left|\Delta_1 + \Delta_{-1}\right| \le \dfrac{4}{\beta_\perp^2 Q_2} \approx 0.025$.

The zone of the automodulation instability is shown in Fig. 3 in the plane of the left and right sidebands' mismatches with the central mode. The zone of the automodulation instability is shown in Fig. 3 in the plane of the left and right sidebands' mismatches with the central mode.

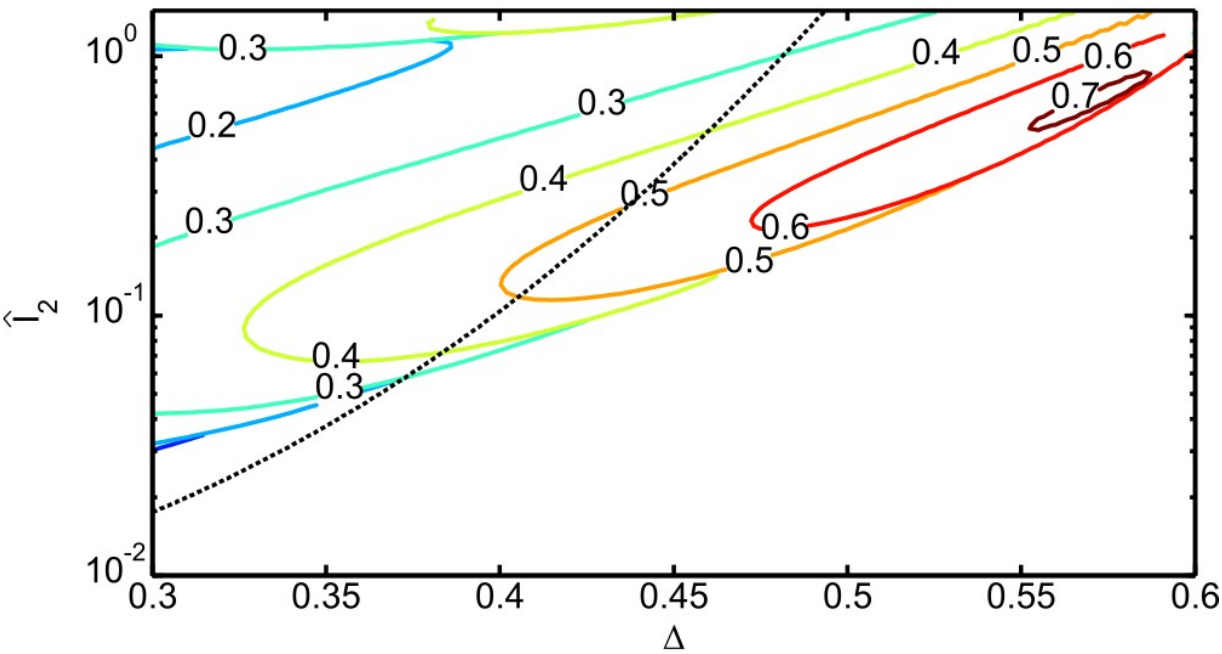

Fig. 2. Contours of equal orbital efficiencies and the start current (dashed line)

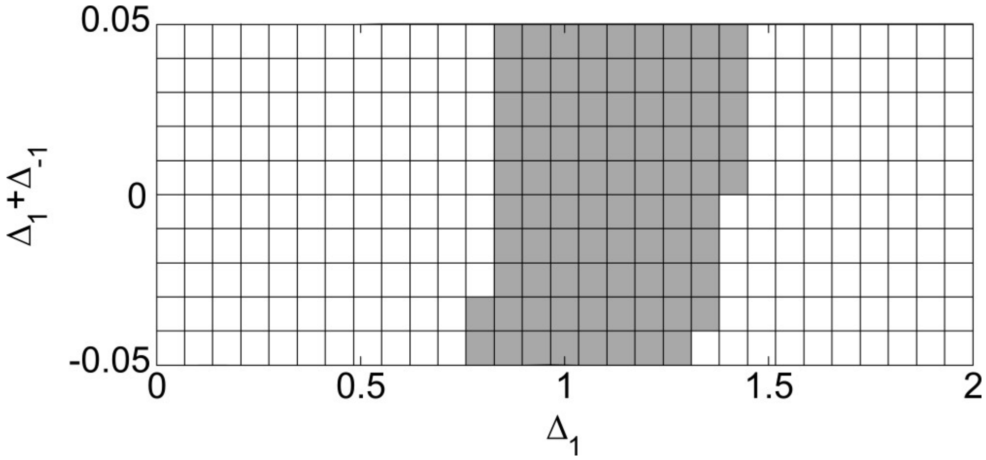

Fig. 3. The zone of the instability of the second harmonic mode.

The difference in the gyrotron operation within the zone of the instability and outside of it was verified by self-consistent simulations of the basic set of equations. Results are shown in Fig. 4.

As seen in Fig. 4a, when the detunings are equal to $\Delta_1 = 0.42, \Delta_{-1} = -0.4$ (this point lies outside of the instability zone shown in Fig. 3), the oscillations of the operating mode are unperturbed. However, when the detunings are equal to $\Delta_1 = 0.82, \Delta_{-1} = -0.8$ (this choice of detunings gives us the point inside the instability zone in Fig. 3), the amplitude of the operating mode is decreased, and the excitation of both sidebands is observed.

The study described above presents the simple theory of parametric interaction of a second harmonic mode with sidebands at the fundamental in gyrotrons. This theory allows calculating the zones of stable single-mode oscillations and helps to select gyrotron parameters for a reliable, stable generation. This theory can be modified to account for the spread in electron beam velocities and guiding center radii and consider the interaction with the modes at the fundamental with several axial variations of the field. Such considerations can lead to the expansion of the zone of instability and softening of the mode density criteria.

The gyrotron operation, when parameters are chosen inside the calculated zone of instability and outside of it, is illustrated by consideration of some examples. It is shown, however, that for typical parameters of the modern gyrotrons (Q close to 1000, accelerating voltage less than 100 kV, and beam pitch-factors 1.2-1.5), the requirements to the mode density (the indices of the operating mode) for occurring such automodulation instability significantly exceed the typical values of mode indices even of the most powerful gyrotrons.

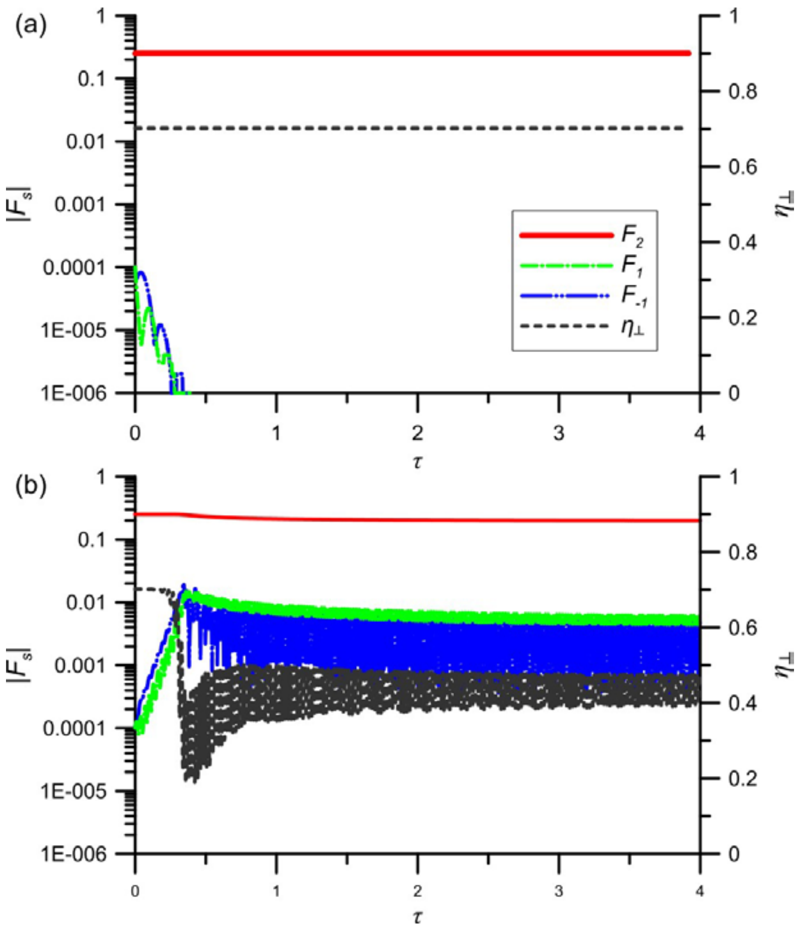

Fig. 4. Time-dependent amplitudes of the operating mode and the satellites outside of the region of instability (a) and inside it (b).

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For more detail, please see the original paper:

A.P.Fokin, V.L. Bakunin, M.Yu. Glyavin, G.S. Nusinovich, “Automodulation instability in gyrotrons operating at the second cyclotron harmonic. Physics of Plasmas, vol. 28 (2021) 043303. DOI: 10.1063/5.0046914

PERSONALIA

Academician Andrei Viktorovich Gaponov-Grekhov at 95

The great Russian physicist Andrey Viktorovich Gaponov-Grekhov, an Academician of the Russian Academy of Sciences was born on 7 June 1926 in Moscow. He is well-known as the founder of the Institute of Applied Physics of the RAS and its first director (1976-2003).

A. Gaponov-Grekhov graduated from Gorky University (now Lobachevsky State University of Nizhni Nogrorod) in 1949. In the same year he entered the postgraduate course to the academician A. A. Andronov. He offered him a topic for his Ph.D. thesis on the general theory of electromechanical systems and in 1955 at the Leningrad Polytechnic Institute he defended his thesis "Electromechanical systems with sliding contacts and the dynamic theory of electrical machines". For the importance of this work, the applicant was immediately awarded the degree of Doctor of Physical and Mathematical Sciences. After completing his postgraduate studies, A.V. Gaponov-Grekhov worked as a teacher at the Gorky Polytechnic Institute (1952-1955), and after receiving his doctorate until 1977 he worked at the State Institute of Physics and Technology (Gorky Research Institute of Physics and Technology, now NIPTI), while remaining a professor at the Polytechnic Institute. On June 26, 1964, he was elected a Corresponding Member of the USSR Academy of Sciences in the Department of General and Applied Physics (Radio Engineering and Electronics), and on November 26, 1968 - an Academician. Since 1966, he worked as Deputy Director of NIRFI, in 1976 he headed the Institute of Applied Physics of the Academy of Sciences of the USSR and directed it until 2003. In 1989-1991 he was elected a deputy of the Supreme Soviet of the USSR. In 2003–2015, he was the scientific director of the IAP RAS, at the present time he is an advisor to the RAS.

Academician Gaponov-Grekhov is an author of fundamental works in the field of electrodynamics, plasma physics, physical electronics, the electrodynamics of a nonlinear medium, and the theory of distributed nonlinear systems. He has conducted theoretical and experimental **research on induced cyclotron radiation, which allowed the development of masers on electron cyclotron resonance (State Prize of the USSR,**

1967) and most notably the gyrotron. His remarkable achievements as a scientist and longstanding leader of the Institute of Applied Physics of the Russian Academy of Sciences (IAP-RAS) in Nizhni Novgorod have been recognized by many highest national and international awards and prizes. Among them are Lomonosov Grand Gold Medal, Hero of Socialist Labor, Order of Merit to the Fatherland, Order of Lenin, Order of the October Revolution, State Prize of the USSR, State Prize of the Russian Federation, and many others.

Professor Grigory Gennadievich Denisov at 65

Grigory Gennadievich Denisov was born on April 30, 1956 in the city of Gorky, now Nizhny Novgorod).

After graduating from the Faculty of Radio Physics of the Gorky State University in 1978, he worked at the Institute of Applied Physics of the Russian Academy of Sciences, first as an intern researcher, then successively as a junior researcher, associate professor, head of laboratory, and head of department. In 1985, under the leadership of Academician A.V. Gaponov-Grekhov, he defended his Ph.D. thesis "Relativistic electron microwave oscillators of the millimeter-wavelength range with highly selective electrodynamic systems", and in 2002 his doctoral thesis "Formation, transformation and transmission of radiation in oversize electrodynamic systems". In 2011, he was elected a Corresponding Member of the Russian Academy of Sciences. Since 2012, he has been the Head of the Plasma Physics and High-Power Electronics Division and Deputy Director for Science at the Institute. Since 11 Jun 2019 he is a Director of IAP-RAS.

Over the years he has become widely known in Russia and abroad for his theoretical and experimental work on electrodynamics of multimode systems and high-power electronics. He is the author of more than 300 scientific papers, 6 author’s certificates, and patents (Hirsch index 36, the number of citations is more than 5000).

In these areas, G. Denisov performed basic works: fundamentally new methods for diagnostics and transformation of the spatial structures of high-power wave beams were proposed and developed and new types of high-power electronic microwave devices were proposed and implemented. Works by G. Denisov determined the successful development of new highly demanded microwave devices with record-breaking parameters, including megawatt gyrotrons for controlled thermonuclear fusion facilities, millimeter-wave gyro-TWT with a wide band of amplified frequencies, and free-electron masers. The results of his work are also very important in the development of promising facilities for the study of new methods of microwave processing of materials to create new sources of multiply charged ions for growing diamond films by CVD technology.

G. Denisov was awarded the Lenin Komsomol Prize for achievements in science (1986), the D. Rose International Prize for achievements in fusion technology (1997), the State Prize of the Russian Federation for achievements in science and technology (2003), Prize of the Government of the Russian Federation for the development of industrial production of megawatt gyrotrons for controlled thermonuclear fusion facilities (2011).

G.G. Denisov is a member of the Scientific Council of the IAP RAS, a member of the IAP RAS dissertation council, the chairman of the expert council of Gycom Ltd, a member of the ITER Scientific and Technical Coordination Council under the State Atomic Energy Corporation "Rosatom", and a member of the expert council of the Ministry of Education and Science. For many years, he has also been conducting teaching work (now as a professor) at the Nizhny Novgorod State University. He prepared a large number of highly qualified specialists in the field of radio physics and high-power electronics, of which seven defended their PhD thesis and one, a doctoral thesis. G. Denisov is the head of the scientific school "Generation, amplification, transformation, and transportation of high-power microwave and terahertz radiation for the purpose of its use in physical and technological research", which combines about 40 scientists, including 8 doctors 14 candidates of science. The school has repeatedly received grants under the program of the President of the Russian Federation on state support of the leading scientific schools.

As a Director of IAP-RAS, Professor G. Denisov actively supports the collaboration of the International Consortium "Development of High-Power THz Science and Technology".

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LIST OF SELECTED RECENT PUBLICATIONS

Bibliography and links to selected recent publications on topics related to the research field of the International Consortium and published after February 2021, i.e. after issuing the previous Newsletter #17. This cumulative list is in chronological order as collected from various bibliographical and alert services

A. Publications by authors from the institutions participating in the International Consortium

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NEWS FROM THE NET (OUR BROADER HORIZONS)

Ultrahigh-sensitivity molecular spectroscopy in the subterahertz range has become a reality

On 11 March 2021 the website Scientific Russia announces that the Institute of Applied Physics of the Russian Academy of Sciences (IAP RAS) has created a subterahertz molecular spectrometer with a record sensitivity for this frequency range (the ability to detect extremely low absorption) 1.3×10^{-11} cm $^{-1}$. The spectrometer combines two unique technologies created at the IAP RAS: a gyrotron, a source of powerful radiation, and a radioacoustic molecular absorption detector.

For more detail on the developed spectrometer please access the publication: G.Yu. Golubyatnikov, M.A. Koshelev, A.I. Tsvetkov, A.P. Fokin, M.Yu. Glyavin, M.Yu. Tretyakov, "Sub-Terahertz High-Sensitivity High-Resolution Molecular Spectroscopy with a Gyrotron," IEEE Trans. on Terahertz Sci. Technol., vol. 10, n. 5 (2020) 502–512. DOI:10.1109/TTHZ.2020.2984459.

Polymer film protects from electromagnetic radiation, signal interference

In her post, Holly Ober announces a breakthrough report published in Advanced Materials—"Electrically Insulating Flexible Films with Quasi-1D van der Waals Fillers as Efficient Electromagnetic Shields in the GHz and Sub-THz Frequency Bands, by Zahra Barani, *et al*. It describes a flexible film using a quasi-one-dimensional nanomaterial filler that combines excellent electromagnetic shielding with ease of manufacture.

"These novel films are promising for high-frequency communication technologies, which require electromagnetic interference shielding films that are flexible, lightweight, corrosion-resistant, inexpensive, and electrically insulating," said senior author Alexander A. Balandin, a distinguished professor of electrical and computer engineering at UC Riverside's Marlan and Rosemary Bourns College of Engineering. "They couple strongly to high-frequency radiofrequency radiation while remaining electrically insulating in direct current measurements."

IEEE Vacuum Electronics Young Scientist Award 2021

Chao-Hai Du was awarded for publishing a monograph related to gyro-TWTs theory and engineering, improving the theory for modeling dielectric-loaded gyro-TWTs, proposing a solution to realize high current axis-encircling electron beams for harmonic gyrotron application, and proposing innovative schemes for developing frequency-tunable THz gyrotrons.
https://vacuumelectronics.org/ivec_award/chao-hai_du.html

A fast and accurate way to optimize fusion energy devices

On 19 April 2021, the Princeton Plasma Physics Laboratory (PPL) reports on a fast and accurate way to optimize fusion energy devices. A model once thought to be nearly impossible for quickly and accurately designing radio frequency (RF) waves needed to fire up doughnut-shaped tokamak fusion facilities has been developed by a graduate student at PPPL. The student, Nick Lopez, has innovated a fast and accurate way to calculate the energy and path of RF waves that are distorted by roadblocks called "caustics" that make the behavior of the waves highly complex. The report cites Lopez who says "Caustics are extraordinarily difficult to describe mathematically in order to simulate — and we need to be able to simulate them to optimize the delivery of RF waves," said Lopez, whose findings are reported in a paper in the Journal of Optics. "The trick is to simulate caustics accurately and we've now found a way to do that."

For more detail, please follow the link to the paper: N.A. Lopez and I.Y. Dodin, "Metaplectic geometrical optics for modeling caustics in uniform and non-uniform media," J. Opt., vol. 23 (2021) 025601. DOI: 10.1088/2040-8986/abd1ce.

OAM Light for Communications

In the June 2021 issue of Optics&Photonics News Alan Eli Willner overviews the possibility to boost the capacity and performance of the optical communication system using light carrying orbital angular momentum. This topic is attracting attention among the gyrotron community since the gyrotrons are natural sources of wave beams with OAM. See for example: M. Thumm, "Gyro-devices – natural sources of high-power high-order angular momentum millimeter-wave beams," Terahertz Science and Technology, vol. 13, no. 1 (2020) 1 – 21. DOI: 10.1051/tst/2020131001. (Open Access).