NEWSLETTER

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

October 2019 № 13

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Second-Harmonic Generation of Sub-Terahertz Gyrotron Radiation by Frequency Doubling in InP:Fe and its Application for Magnetospectroscopy of Semiconductor Structures

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In recent decades, an unprecedented increase in activity in the terahertz (THz) range of the electromagnetic spectrum has been observed around the world. The giant spread of studies into the possibility of using THz radiation in a variety of very important applications suggests that today this range proves to be at the forefront of investigations and developments.

The difficulty in creating efficient terahertz sources is related to the fact that, in the terahertz range, well-developed methods for generating optical and microwave radiation are poorly applicable. Powerful sources of terahertz radiation are synchrotrons and free-electron lasers; however, a high cost and large sizes prevent their wide use even for purely scientific applications. The classical devices of vacuum electronics barely achieve the frequency limit of 1 THz, and their radiation power in this range does not exceed 1 mW. The difficulties in increasing the operating frequency of such vacuum sources are associated with those in manufacturing a small-scale deceleration system. In gyro-devices, the radiation frequency is limited by the magnetic field strength and by the necessity of selection when working at gyrofrequency harmonics, which usually requires complex technical solutions. On the other hand, since the equivalent temperature of 1 THz radiation is only 47.6 K, the thermal relaxation of levels at room temperature leads to the rapid destruction of inversion in lasers. Thus, quantum-cascade lasers, which occupy the leading positions among compact semiconductor sources in the mid-infrared range, operate at terahertz frequencies only under conditions of cryogenic cooling.

The main methods for generating terahertz radiation in semiconductor structures are reduced to the optical rectification of short-wavelength radiation pulses, the generation of a difference frequency when using parametric light generators as a pump, and also the initiation of fast transient processes upon the excitation of a semiconductor in lasers with a short optical pulse. Sources of terahertz radiation based on femtosecond lasers have an extremely wide emission spectrum (~1 THz), which is not always acceptable. In addition, the output power in all the above methods is low. At the moment, for the generation of terahertz radiation by the optical rectification method, as a rule, ZnTe, GaP, and $LiNbO_3$ crystals are used. For all of them, fairly large losses in the terahertz range are characteristic.

One of the ways of obtaining intense terahertz radiation is by multiplying the radiation frequency due to various types of nonlinearity in semiconductor structures. As is known, generation of the second harmonic due to second-order lattice nonlinearity is possible only in crystals in which there is no center of inversion. The lattice nonlinearity was studied in gallium arsenide: a CH_3F gas laser with frequencies in the range of 0.6–1.7 THz and a free-electron laser were used as the radiation source. It should be noted that the nonlinear properties of III–V materials are studied very poorly in the far-IR region, where the frequency dispersion of the nonlinear second-order coefficient is significant. According to our information, there is only one theoretical study devoted to these problems, and there are several experimental studies.

The development of gyrotrons with an operating frequency in the terahertz range is carried out in almost all research centers around the world specializing in vacuum electronics. At present, subterahertz gyrotrons operating with sufficiently high power in both the pulsed and continuous-wave modes have already appeared. The doubling of the radiation frequency of such lamps makes it possible to obtain narrow-band (several MHz) radiation in the range of 0.5–1.1 THz with the ability to tune the radiation frequency within 1 GHz and, in the future, achieving a frequency of 2– 2.5 THz. In this case, a high pump-radiation power makes it possible to rely on obtaining a high radiation power at the second harmonic even at room temperature.

In this study, we investigated the possibility of doubling the radiation frequency of a gyrotron operating at the fundamental cyclotron harmonic with the generation of a frequency of 0.263 THz. As already mentioned, the generation of the second harmonic due to the second-order lattice nonlinearity is possible only in crystals in which there is no center of inversion. Despite relatively high values of the second-order nonlinear susceptibility, the acquisition of a low residual concentration of free carriers is a difficult technological problem for many common semiconductors. Among the materials for which this problem was successfully solved, indium phosphide should be noted, in which, in addition, the magnitude of the nonlinear susceptibility is more than six times higher than the second-order nonlinear susceptibility in the GaAs semiconductor, which is the best studied in this respect.

One of the factors complicating the experimental study of gyrotron-frequency doubling in semiconductor structures is the presence of harmonic components of the cyclotron frequency in the emission spectrum of gyrotrons due to the nonlinearity of the electron beam in the strong signal mode. To compare the evaluation of the frequency-doubling efficiency with the intensity of gyrotron self-radiation at the second harmonic, the gyrotron emission spectrum was experimentally investigated using notch filters based on the cyclotron resonance in semiconductor structures. For this purpose, ~10% of the gyrotron radiation was diverted to the measuring path consisting of an oversized waveguide coupled with a Michelson or Mach– Zehnder interferometer, at the output of which a supercritical waveguide was mounted, which cut off the fundamental harmonic at 263 GHz and transmitted the radiation at a doubled frequency of 526 GHz.

Further, the radiation was introduced through a waveguide insert into an STG-40 Dewar transport vessel, in the lower part of which a superconducting magnet was located, which enables us to obtain a magnetic field of up to 3 T when cooling with liquid helium. As a notch filter, a structure with a HgTe/$Cd_{0.65}Hg_{0.35}Te$ quantum well 20 nm wide grown by molecular-beam epitaxy on a GaAs substrate and doped with indium to concentrations of ~10^{17} cm^{-3} in barriers was located inside the magnet. Due to the small effective masses of electrons in such structures, the cyclotron resonance at a frequency of 0.263 THz is observed in relatively low magnetic fields of ~0.3 T. When a field corresponding to cyclotron resonance was achieved, the transmission of the structure sharply decreased, which led to a drop in the signal at the InSb-based photoelectric receiver located at the end of the waveguide insert behind the magnet. Thus, the described measuring setup made it possible to perform express analysis of the spectral composition of the radiation. The magnitude of signal suppression at the fundamental harmonic in the supercritical waveguide and the modulation depth in the used interferometers were measured individually in the range of linearity of the InSb-receiver response, and the possibility of continuously varying the gyrotron radiation power from 1 W to 1 kW was applied. The combination of the interferometer and the supercritical waveguide enabled us to attenuate the intensity of the first harmonic by about three orders of magnitude.

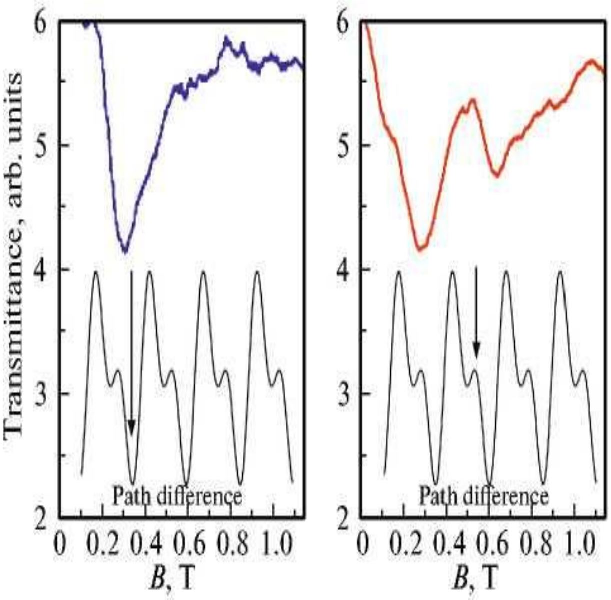

Fig. 1. Spectra of magnetic transmission of a sample based on HgCdTe at different values of the path difference (marked by an arrow on the interference patterns - see insets below) in a Michelson interferometer used as a second harmonic filter.

Depending on the receiver-signal magnitude at the path difference in the spectrometer arms, we found weak peaks located between the principal ones in addition to them corresponding to radiation at the fundamental harmonic. The nature of the observed interference pattern is shown schematically in the inset to Fig. 1, which also shows the magnetic-transmission spectra obtained with a gyrotron radiation power of 80 W. It can be seen that, in the position of the interferometer corresponding to the transmission minimum, the magnetic-transmission spectrum contains a single line of cyclotron resonance corresponding to a gyrotron emission frequency of 0.263 THz.

When the interferometer is in the position corresponding to an “additional” peak, a second line appears in the magneto- transmission spectrum, the peak of which corresponds to a magnetic field twice as high, i.e., to the second harmonic. Measurements at other gyrotron powers showed that the average ratio of the intensity of the second harmonic to the first one lies in the range of 0.001–0.005.

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It is easy to estimate that, for a radiation intensity of 8 kW/cm^2 at the principal harmonic discussed above, doubling at a crystal with a length of ~7 cm gives a comparable intensity of radiation at the second harmonic. However, in the case of pulsed gyrotrons, higher radiation intensities are available, which can significantly increase the conversion efficiency. It should be noted that an increase in the efficiency with frequency is compensated by the increasing dispersion of refraction and absorption in InP:Fe; however, we can expect to obtain a radiation intensity an order of magnitude larger at the doubled frequency than the intrinsic radiation of the gyrotron at the second harmonic.

To cut off radiation at the fundamental harmonic of 263 GHz and transmit radiation at a double frequency of 526 GHz, as well as focus the radiation into a spot with a diameter of 2.5 mm, to provide a power density of about 15 kW/cm^2 at 263 GHz, a shielded case was specially designed. The shielded box is equipped with water cooling over the entire surface. A photograph demonstrating the general view of the box is shown in Fig.2.

Fig. 2. Shielded box design for focusing the radiation on the fundamental frequency (gyrotron part on the left side).

We conclude that employing high-resistivity InP:Fe crystals is a promising route to obtain THz radiation by doubling the frequency of intense gyrotron radiation. For realistic gyrotrons, at least 1% conversion efficiency is achievable in InP wafers, corresponding to the second harmonic power of 60–100 W/cm^2 in 0.5–1.2 THz frequency range. According to studies of the gyrotron radiation, this is an order of magnitude higher than the intensity of the second harmonic available from the gyrotron. The possibility of using second-harmonic radiation for the magnetospectroscopy of semiconductor structures is shown.

For more detail: V.V. Rumyantsev, at al. Semiconductors **53**, 1217–1221 (2019).

Methods of Enhancing the Gyrotron Operation Selectivity and Efficiency Using Special Corrugations of the Cavity Wall

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Recently, two novel methods of improving the gyrotron operation have been proposed [1-3]. Both of them are based on a certain deformation of the gyrotron cavity walls and have been confirmed by comprehensive numerical simulations. Here we briefly summarize the essence of these methods and corresponding numerical results.

Decreasing the Ohmic losses in long cavities

The first method may be useful when one has to use a very long cavity to provide the gyrotron excitation. This is often the case for weakly-relativistic tubes operating at high cyclotron harmonics, where the long cavity is necessary to compensate for the weak electron-wave coupling. In conventional cylindrical cavity, and especially in the THz frequency range, this leads to a very high ratio of the diffraction and Ohmic quality factors, so that the share of Ohmic losses may exceed 90%. To decrease the diffraction Q-factor, the operation at higher axial modes can be used, since the efficiency of the radiated power extraction increases with the operating wave group velocity. Unfortunately, the efficiency of the radiation itself rapidly decreases for higher axial modes mainly due to increasing sensitivity of the operation to the velocity spread in the electron beam. In its turn, such sensitivity is a consequence of the cyclotron resonance condition, which includes depending on the electron velocity Doppler term:

$$\omega \approx n\Omega_c \pm (l\pi/L)v_\parallel \ , \tag{1}$$

where ω and Ω_c are the operating and electron cyclotron frequencies, n is the cyclotron harmonic number, L is the cavity length, l is the axial mode index, $v_\parallel$ is the axial electron velocity, and +/- sign depends on which one of the forward and backward partial waves of the mode interacts with the electron beam. This Doppler term arises from the requirement that the electron stays in phase with the propagating partial wave as it moves along the cavity. In the case of the fundamental axial mode excitation, the electrons interact with both partial waves, so that the condition (1) does not contain electron velocity, and the operation becomes almost insensitive to the velocity spread:

$$\omega \approx n\Omega_c \ . \tag{2}$$

To overcome the described problem we proposed to use several short widenings of the cavity wall placed near the field zeroes of the desired high axial mode. These irregularities act as phase correctors, adding an extra π-shift to the wave phase. As a result, instead of changing its sign in points along the cavity axis, the operating mode becomes almost unipolar (Fig. 1) and, consequently, well couples with the electron beam in the regime of gyrotron resonance (2). Besides, the phase correctors affect also the axial structure of the fundamental gyrotron mode, which now acquires $(l-1)$ close-to-π phase shifts along the axis leading to the corresponding dependency of the excitation efficiency on the velocity spread.

The proposed scheme was simulated using two independent methods. It should be noted, that the natural desire when designing the cavity is to make the total length of the phase correctors as small as possible so that their influence on the electron-wave interaction be minimized. This does not allow one to use a common for the slightly-irregular cavities approach based on non-uniform string equation for the operating mode since the assumption of slow cavity radius change necessary for such an approximation is often violated near the phase correctors. Instead, one has to take into account possible transformations of the operating mode into other radial modes. Therefore, the first method we used is based on the coupling waves approximations, when the cavity field in every cross-section is treated as a sum of mutually-scattering waveguide modes, propagating in a waveguide of the same cross-section. In order to illustrate the method, we designed a cavity with $TE_{4,8}$ operating mode and two phase correctors. The correctors have a form of a triangle with the base length of $\sim 4\lambda$, for which the condition of non-uniform string approximation applicability is essentially violated, and the single-mode approximation should be inadequate.

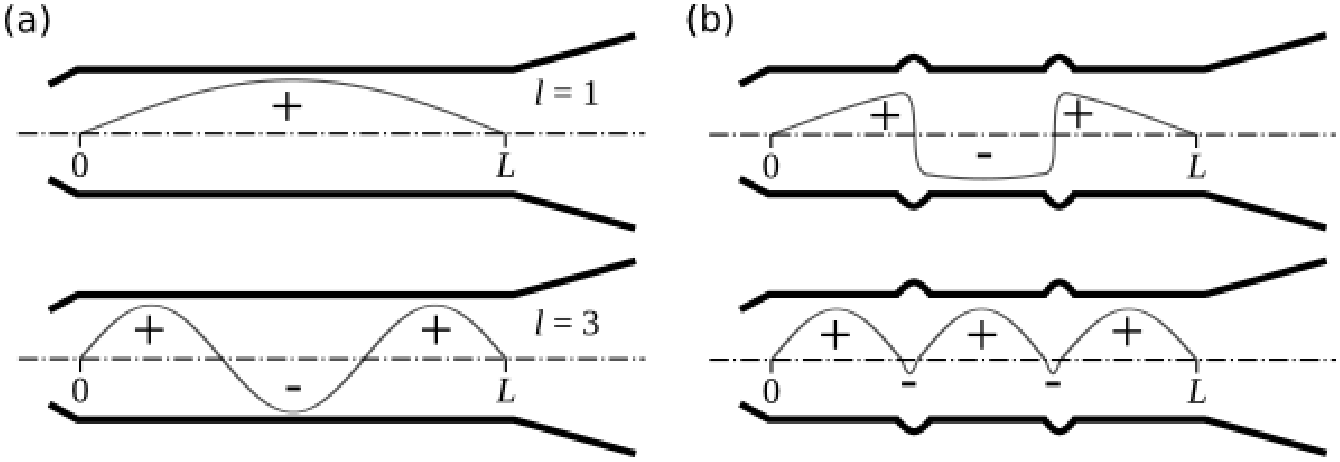

Fig. 1. Schematics of the conventional gyrotron cavity (a) and the cavity with phase correctors (b). Transformations of the fundamental axial mode and of the mode with three axial variations are shown.

Fig. 2a,b shows the results of the cavity spectrum analysis, which include the resonance response of the cavity when it is fed from the collector side as a function of feeding signal frequency, as well as the cavity eigenmode profiles. The eigenmodes are obtained as the solution of the eigenvalue problem with radiation boundary conditions. Fig. 2a shows these characteristics obtained in a single-mode approximation, and Fig. 2b takes into account modes conversion. It is evident, that the simple explanation of the scheme (Fig. 1) is adequate in common and predicts the transformation of the conventional cavity modes in a right way. At the same time, considering the scattering is essential for correct describing the modes profiles and, especially, Q-factors. It may be seen, that both the frequency and the Q-factor of the operating $TE_{4,8,3}$ mode are very weakly sensitive to cavity wall corrugation, as well as to the modes scattering. Mainly, this is because the correctors are positioned near the zeroes of the mode. On the contrary, the other modes, and especially the fundamental near-to-cutoff mode, are substantially distorted by the phase correctors, which also demonstrates the high selective properties of the proposed scheme.

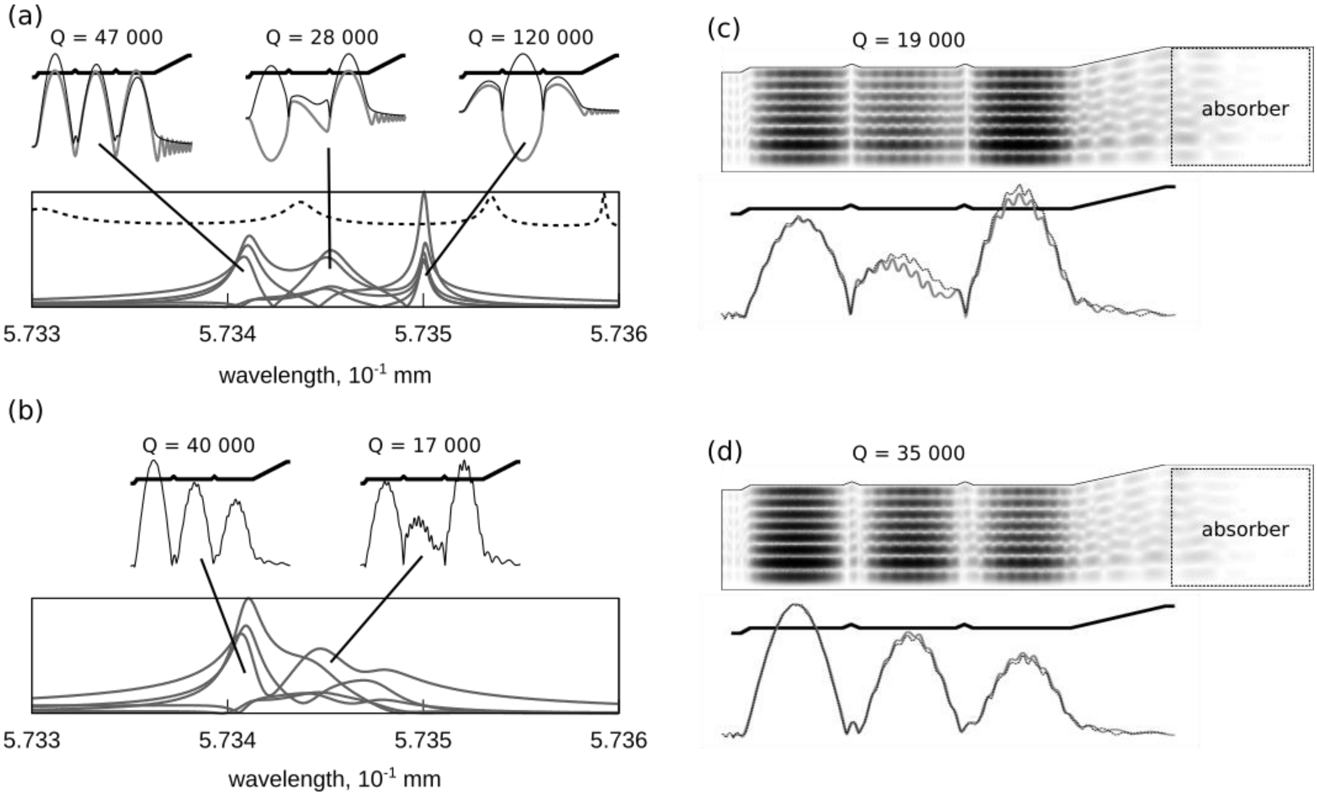

Fig. 2. Results of 1-D (a,b) and Finite Element Method (c,d) simulations. (a,b) : Response of the cavity when it is fed from the collector end, taken in various axial points, and profiles of the eigenmodes field amplitudes with correspondent diffractive quality factors in single-mode (a) and multimode (b) approximations. In (a), the dashed curve is the response of the conventional regular cavity, and gray curves in the profiles are the real parts of the complex amplitudes. (c,d) : Eigenmodes field patterns and diffractive Q-factors obtained by the finite element method, as well as comparison of the axial field profiles obtained by this method (gray curves) and by the 1-D approach (black dotted curves). The results correspondent to cases of $l = 2$ (a) and $l = 3$ (b) are shown.

The 1-D approach based on coupling waves is very convenient for applying it in “hot” gyrotron simulations since it allows explicit introducing of the amplitude of the resonant (in sense of the condition (2)) radial mode in the equations of electron motion. Nevertheless, to be sure that the obtained numerical results are correct, we have made additional simulations of the “cold” scheme on the basis of more straightforward approach of solving the Maxwell equations by the finite element method. The patterns of the azimuthal electric field amplitude, as well as the comparison of the axial modes profiles obtained by the two approaches, are shown in Fig. 2c,d. Evidently, the results of different simulations are in good agreement, which validates our conclusions.

The designed cavity was then used for numerical simulations of the fourth-cyclotron-harmonic 30 kV Large Orbit Gyrotron, where it demonstrated a possibility to decrease the share of Ohmic losses from 95% predicted for the conventional cylindrical cavity down to 60%, which not only increases the output efficiency but also significantly decreases the cavity heating during the CW operation.

Increasing the high-harmonic operation selectivity of an oversized cavity

Another method based on the cavity deformation allows essential discrimination of the parasitic low-frequency excitations in a high-cyclotron-harmonic gyrotron even when operating in a quite overmoded cavity. In a certain sense, this method originates from the one described in the previous section and further develops its selective properties. The main idea is to make a short deformation of the cavity wall which has minimal effect on the operating mode, but dramatically affects all the parasitic modes. It turns out that a possible solution is introducing a rectangular groove with very special, resonant dimensions. The effect of these resonant dimensions is a complete “invisibility” of the groove for the operating mode so that the field profile in the electron beam position and the quality factor remain the same as in the original regular cavity. On the parasitic modes, on the contrary, this groove has a strong scattering effect, which decreases their Q-factors and spoils the axial field profiles, thus significantly increasing their starting currents.

To demonstrate the method, we simulated a modification of the cavity of a 670 GHz gyrotron operating at the fundamental cyclotron resonance at the TE$_{31,8}$ mode [4]. An analysis of the eigenmodes spectrum of this cavity shows (Fig. 3a,b) that in the operating range of magnetic fields, the resonance is possible at the second cyclotron harmonic at the TE$_{63,15}$ mode at 1.34 THz. Nevertheless, in the traditional cylindrical system, the starting current of this mode is slightly higher than the starting current of the low-frequency modes TE$_{30,8}$ and TE$_{31,8}$ excited at the fundamental cyclotron resonance (Fig. 4a). To discriminate these modes, we proposed to apply a groove with a depth of about 0.12 mm to the cavity wall having a radius of 4.54 mm. With this depth, the radius of the resonator inside the groove approximately corresponds to the critical radius for the TE$_{63,16}$ mode. The longitudinal position of the groove along the axis of the resonator divides its length in the ratio 1 to 3 (Fig. 5), which makes it possible to discriminate not only the fundamental but also higher axial parasitic modes with two variations of the field.

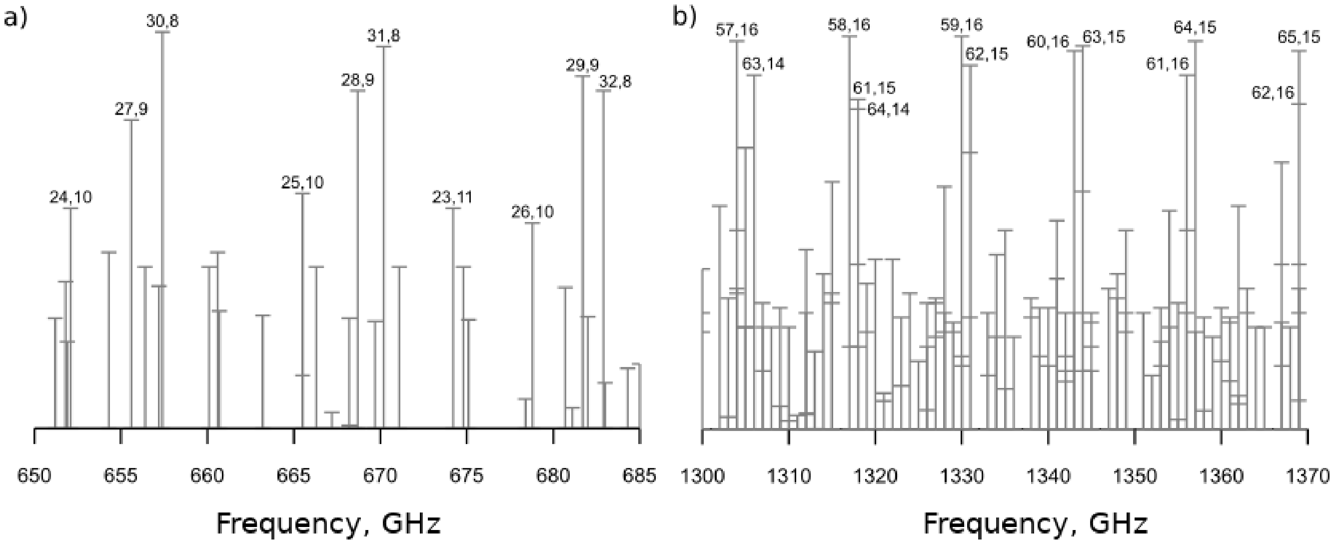

Fig. 3. Eigenmodes spectrum of the regular 670 GHz gyrotron cavity in the vicinity of the first (a) and second (b) cyclotron harmonics. The relative heights of the bars correspond to the modes coupling strength for a given electron beam radius of 2.3 mm. Only modes with strongest coupling are labeled.

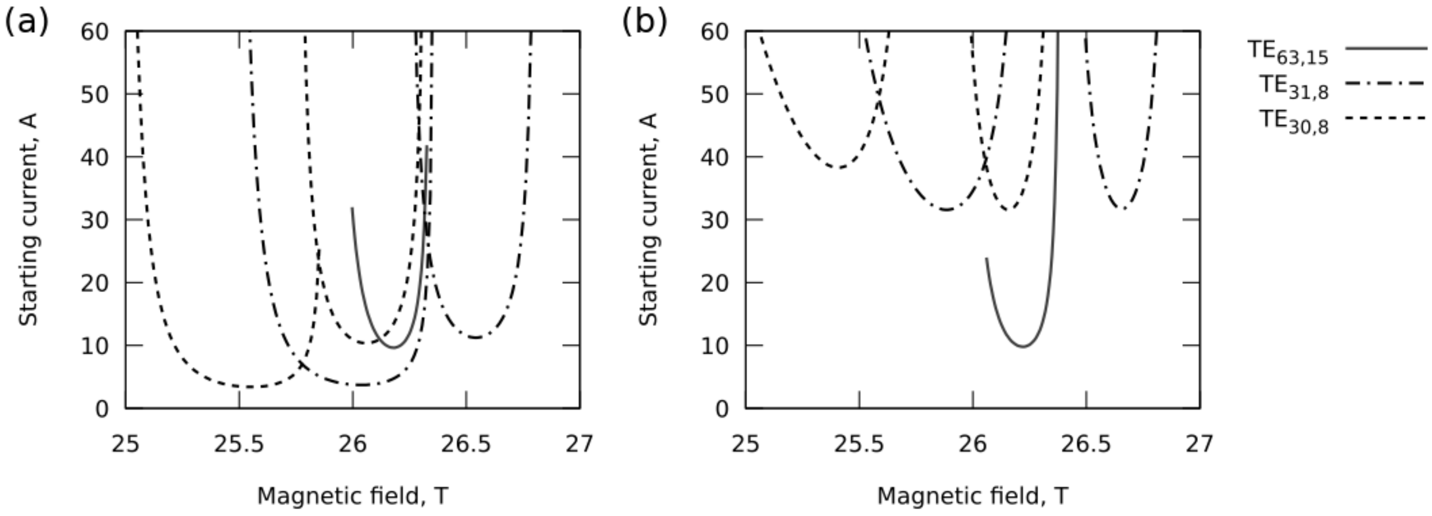

Fig. 4. Starting currents of the fundamental and second cyclotron harmonic oscillations in the regular (a) and modified (b) gyrotron cavity.

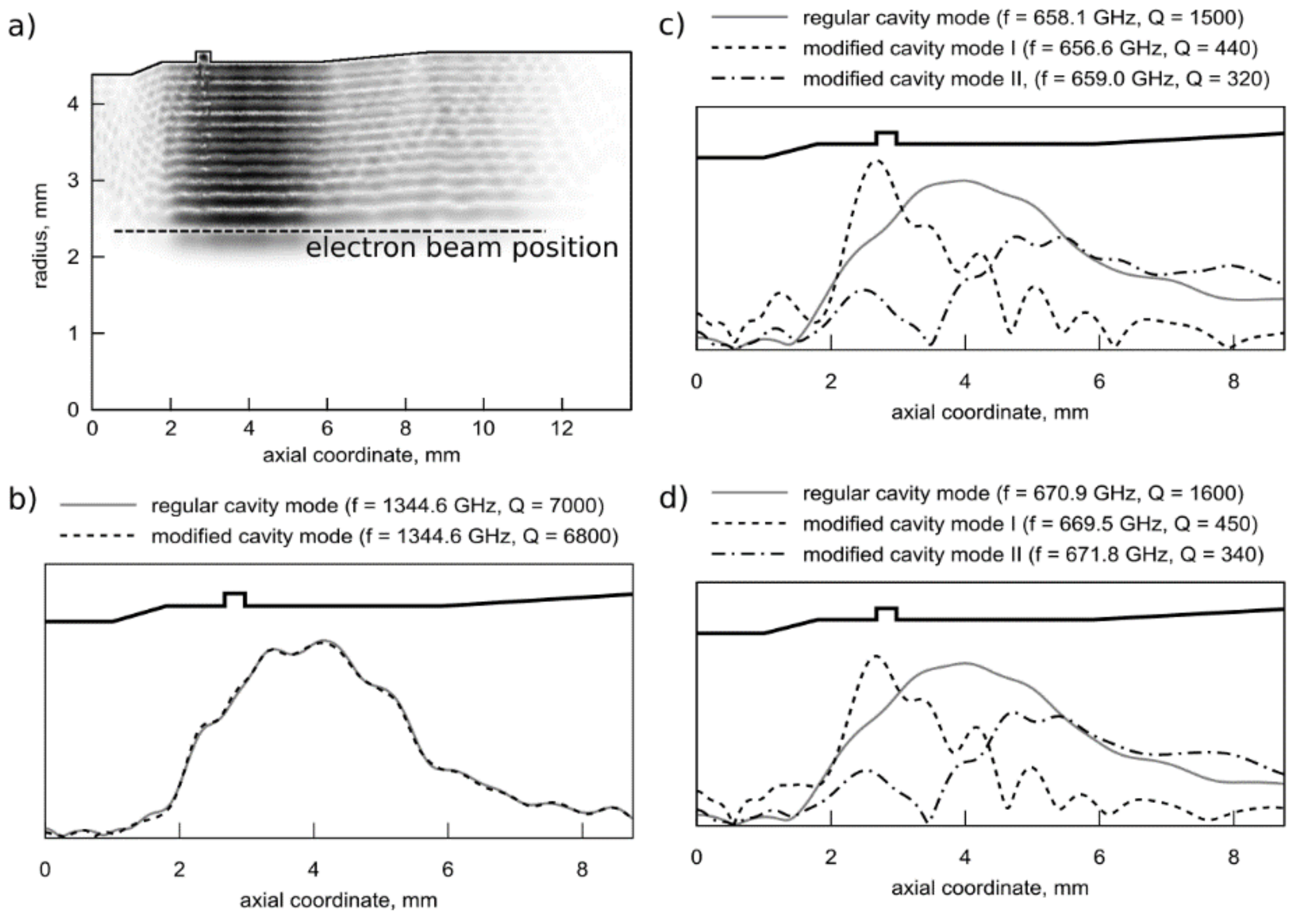

Fig. 5. Results of electrodynamic cavity simulations. A two-dimensional *(r-z)* pattern of the azimuthal electric field of the $TE_{63,15}$ mode in the presence of the groove (a) and comparison of the axial profiles of the $TE_{63,15}$ (b), $TE_{30,8}$ (c) and $TE_{31,8}$ (d) modes in the vicinity of the electron beam for the regular and modified cavity. In the modified cavity, two modes with approximately equal low Q-factors appear in the last two cases, which are actually the descendants of the two lowest axial modes of the regular cavity.

The eigenmodes of the modified resonator were again calculated by the Finite Element Method for the Maxwell equations. By choosing the geometric dimensions of the groove, we managed to achieve its almost complete “transparency” for the $TE_{63,15}$ mode, keeping both the quality factor of this mode and the longitudinal field profile in the position of the electron beam unchanged (Fig. 5a,b). The latter is an important feature that distinguishes this method from the one described in the previous section. Namely, in this case, the field profile remains unchanged even inside the groove, whereas the region located inside the phase corrector drops out of the electron-wave interaction. Calculation of the eigenmodes of the modified resonator near the resonance at the first cyclotron harmonic, as expected, demonstrated a strong distortion of the longitudinal profiles of these modes with respect to the unperturbed system and a significant decrease in their Q-factors (Fig. 5c,d).

Calculation of the starting currents confirmed the effectiveness of discrimination of parasitic modes in the proposed resonator (Fig. 4b). The deformation of the low-frequency modes turned out to be so strong that their starting currents became several times greater than the practically unchanged starting current of the operating mode at the second cyclotron harmonic.

Conclusion

Comprehensive numerical simulations prove the capability of the proposed methods to essentially decrease the share of Ohmic losses and to increase the operation selectivity. These methods may be especially useful when applied in high-harmonic gyrotrons operating in the THz frequency range.

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NEWS FROM THE MEMBERS OF THE CONSORTIUM

150th Anniversary of the Bulgarian Academy of Sciences

Established on 12 October 1869, the Bulgarian Academy of Sciences (BAS) is the oldest institution in modern Bulgaria. It carries out scientific work in accordance with the universal values, national traditions, and interests. The Bulgarian Academy of Sciences is the leading scientific, spiritual and expert center of Bulgaria. It conducts research, training, and activities of national and international importance and solves problems related to the development of Bulgarian society and state.

Today, BAS comprises 42 scientific institutes and 8 specialized units. One of them is the **Institute of Electronics**, which is a **longstanding collaborator to FIR UF and a member of the International Consortium on the Development of the High-Power Terahertz Science and Technology**. The Academy employs about 3,000 scientists, accounting for about 15% of those engaged with science in Bulgaria. BAS produces about half of the scientific output in the country. The main divisions in which the institutes of the Academy conduct fundamental and applied studies and training are:

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  - Institute of Mechanics
  - Institute of Robotics
  - Institute of Information and Communication Technologies
  - National Laboratory of Computer Virology
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The 150th Anniversary of the Academy has been marked by a commemorative post stamp, a silver coin, and many celebrations. For more information please visit the website of the BAS.

ИПФ РАН Institute of Applied Physics
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Researchers from IAP-RAS won young scientists grant

A project led by Dr. Andrey Fokin in collaboration with Dr. Ilya Bandurkin and Dr. Ivan Osharin from IAP-RAS has won a grant from the Russian Science Foundation in the framework of the presidential program for support of projects conducted by leading scientists including young researchers. The title of the projects is: “Terahertz gyrotrons operating at high cyclotron harmonics with super-selective resonators.”

A. Fokin and I. Bandurkin – researchers from IAP-RAS and collaborators of FIR-UF

The project aims to develop compact sources of intense (tens of watts) narrow-band terahertz radiation in the frequency range 0.5 - 1.5 THz, which is demanded by many novel applications in various fields of the high-power Terahertz science and technologies such as for example terahertz vision, selective effects on cancer cells treatment and high resolution tomography. The problem of creating relatively intense (with a power of at least tens of watts) and, at the same time, commercially available to a wide range of consumers (in terms of both compactness and cost) radiation sources with a frequency of about 1 THz and above is still not resolved. At present, the need for sources of terahertz radiation is dictated by such relevant applications as spectroscopy and diagnostics of various media, terahertz vision, and remote sensing of hazardous substances, biophysical and biochemical studies, etc. The main objective of the project will be the search and demonstration of ways to push a very advanced class of sources of coherent electromagnetic radiation - electron cyclotron masers (gyrotrons) – forward into the area of parameters not yet mastered by these generators, but very important for applications. The uniqueness of the developed sources is determined by a combination of several factors at once: radiation frequency above 1 THz, relatively low magnetic fields due to operation at high cyclotron harmonics, output power at the level of tens of Watts and above, operation in continuous generation regime. Moreover, the use of low operating magnetic fields, as well as electron beams with relatively low energy, should ensure the compactness of such sources and, accordingly, their availability to a wide range of consumers. The project will include the development and creation of compact gyrotrons with moderate energetics of working electron beams (particle energy – tens of keV, current – several A), in which the selectivity of the excitation of oscillations at high harmonics of the cyclotron frequency will be achieved through the use of new electrodynamic systems with discrimination of parasitic oscillations at low cyclotron harmonics. The efficiency of the approaches proposed by the authors will be tested in a number of demonstration experiments both in the millimeter and in the sub-mm wavelength range. Within the framework of this project, in order to increase the selectivity of generation in gyrotrons, it is planned to explore the original approach, developed with the direct participation of the project authors, and based on the modification of the gyrotron resonator by applying scattering elements (rectangular grooves) to the side wall. As shown in the previous theoretical works of the authors of the project, such selection elements can have a significant destructive effect on the parasitic low-frequency oscillations, almost without effect on the operating mode. In the course of the project, an experimental verification of this possibility is planned.

The uniqueness of such radiation source, in addition to the record high frequency for this class of devices, is determined by a combination of several other factors important for the users, namely, the relatively high generation power when operating in continuous-wave regime and compactness of the device. Currently, there are no analogs of such systems in the world. Undoubtedly, generators of this type will be in demand for a number of important problems arising in such fundamental applications as spectroscopy and diagnostics of various media, technical applications in the field of security control and countering terrorism, biophysical and biochemical studies, etc.

Source: IAP-RAS

FORTHCOMING EVENTS

IRMMW-THz 2020
Buffalo

September 13–18, 2020

45th International Conference on Infrared, Millimeter, and Terahertz Waves

Buffalo Niagara Convention Center
Buffalo, New York, USA

Conference Co-Chairs

Andrea Markelz University at Buffalo, USA
Erik Einarsson University at Buffalo, USA

Technical Program Chair

Frank Hegmann University of Alberta, Canada

Local Organizing Committee

Priya Banerjee University at Buffalo, USA
Luis Velarde University at Buffalo, USA
John Cerne University at Buffalo, USA
Vladimir Mitin University at Buffalo, USA
Peter Q. Liu University at Buffalo, USA

Important Dates

11 Nov 2019	Call for abstracts
20 Mar 2020	Abstract submission deadline
04 May 2020	Notification of acceptance
12 June 2020	Early registration deadline
03 July 2020	Extended abstract deadline

News & Updates

Conference website
www.irmmw-thz2020.org
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TERA 2020

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International Conference

Terahertz and Microwave Radiation: Generation, Detection and Applications

TERA-2020 conference is devoted to the discussion of fundamental and applied problems related to the generation and detection of terahertz and microwave radiation as well as its interaction with matter.

Tomsk, Russia, 2020

[Announcement of TERA-2020 in Tomsk (*.PPTX)]
[Pre-registration]

Contacts: Yury Kistenev, yv.kistenev@gmail.com
Last Event: **TERA-2018**

GEMIC
GERMAN MICROWAVE CONFERENCE

The 13th German Microwave Conference 2020, March 09–11, will be hosted by Brandenburg University of Technology Cottbus-Senftenberg in cooperation with IMA e.V. and VDE/ITG. GeMiC 2020 provides a unique platform to exchange with experts and to meet colleagues from industry, research institutes, and universities.

Download Call for Papers

Website of the conference

ICMTT 2020: 14. International Conference on Microwave and Terahertz Technology

June 04-05, 2020 in New York, United States

For more details follow the link.

ICTSTA 2020: 14. International Conference on Terahertz Science, Technology and Applications

July 16-17, 2020 in Copenhagen, Denmark

For more details follow the link.

ICMTT 2020: 14. International Conference on Microwave and Terahertz Technology

August 20-21, 2020 in Bangkok, Thailand

For more details follow the link.

ICTSTA 2020: 14. International Conference on Terahertz Science, Technology and Applications

September 17-18, 2020 in Amsterdam, Netherlands

For more details follow the link.

ICATSE 2020: 14. International Conference on Advances in Terahertz Science and Engineering

September 24-25, 2020 in London, United Kingdom

For more details follow the link.

ICTSE 2020: 14. International Conference on Terahertz Science and Engineering

October 15-16, 2020 in Rome, Italy

For more details follow the link.

For more details follow the link.

ICTS 2020: 14. International Conference on Terahertz Science

June 29-30, 2020 in London, United Kingdom

For more details follow the link.

ICATSE 2020: 14. International Conference on Advances in Terahertz Science and Engineering

September 24-25, 2020 in London, United Kingdom

For more details follow the link.

ICTSEA 2020: 14. International Conference on Terahertz Science and Engineering Applications

September 17-18, 2020 in Rome, Italy

For more details follow the link.

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 June 2019, i.e. after issuing the previous Newsletter #12. This cumulative list is in chronological order as collected from various bibliographical and alert services

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C Patents

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Inventors: Gojkhman Mikhail Borisovich (RU), Gromov Aleksandr Viktorovich (RU), Palitsin Aleksej Valentinovich (RU)
Russian Federation Invention: 2019100408
Date of publication: 06.08.2019 Bull. № 22
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Methods and devices for producing an electron beam
Inventors: Einat, Moshe (Ariel, IL); Orbach, Yafit (Ariel, IL); Pilossof, Moritz (Ariel, IL)
US Patent Application: 20190272968
Date of publication: 09/05/2019
http://www.freepatentsonline.com/y2019/0272968.html

System and method for launching guided electromagnetic waves with impedance matching
Inventors: Rappaport, Harold Lee (Middletown, NJ, US)
US Patent: 10305192
Date of publication: 05/28/2019

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Transmission device with impairment compensation and methods for use therewith
Inventors: Barzegar, Farhad (Branchburg, NJ, US); Gerszberg, Irwin (Kendall Park, NJ, US); Bennett, Robert (Southold, NY, US); Henry, Paul Shala (Holmdel, NJ, US)
US Patent: 10355790
Date of publication: 07/16/2019
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Method and apparatus of communication utilizing waveguide and wireless devices
Inventors: David M. Britz, John W. MacNeill, David DeVincentis, Robert Bennett, Paul Shala Henry, Irwin Gerszberg, Farhad, Barzegar, Thomas M. Willis, III, Donald J. Barnickel
US Patent: 20190007096A1
Date of application granted: 06/08/2019
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Triode electron gun
Inventors: Allen, Curtis (Redwood City, CA, US)
US Patent Application: 20190272969
Date of publication: 09/05/2019
http://www.freepatentsonline.com/y2019/0272969.html

Apparatus and method for guided wave communications using an absorber
Inventors: Paul Shala Henry, Giovanni Vannucci, Thomas M. Willis, III
US Patent: US20190173151A1
Date of publication: 06/06/2019
https://patents.google.com/patent/US20190173151A1/en

System and method for identifying materials using a THz spectral fingerprint in a media with high water content
Inventor: Patrick K Brady
US Patent: 10401283B2
Date of publication:
https://patents.google.com/patent/US10401283B2/en

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The Nobel Prizes in Physics and Chemistry 2019

The Nobel Prize in Physics 2019 was awarded "for contributions to our understanding of the evolution of the universe and Earth's place in the cosmos" with one half to James Peebles "for theoretical discoveries in physical cosmology", the other half jointly to Michel Mayor and Didier Queloz "for the discovery of an exoplanet orbiting a solar-type star."

For more details please see the press release at the following link.
Source: The Nobel Prize in Physics 2019. NobelPrize.org. Nobel Media AB 2019. Wed. 9 Oct 2019

Akira Yoshino, honorary fellow at Asahi Kasei Corp., has won this year's Nobel Prize in Chemistry, the Royal Swedish Academy of Sciences announced on Oct. 9 in Stockholm. Yoshino, 71, a professor at Meijo University, shares the prize with two other researchers for the development of lithium-ion batteries. The co-laureates are John Goodenough of the University of Texas, and M. Stanley Whittingham of Binghamton University, State University of New York. The Royal Swedish Academy of Sciences said lithium-ion batteries -- "secondary cell" rechargeable and reusable batteries widely used in mobile phones and laptop computers -- "have revolutionized our lives." With this award, the number of Japanese Nobel laureates has become 27 altogether.

Source: The Mainichi

Chopping megawatt-level output power of gyrotron for particle acceleration

In a posting of August 12, 2019, the MIT News reported that Julian Picard was awarded the Outstanding Student Paper Award from the IEEE Nuclear and Plasma Sciences Society at the 2019 Pulsed Power and Plasma Science Conference in June for a paper published in the journal Applied Physics Letters, which describes a method to “chop” the pulse of a powerful gyrotron with a megawatt-level output power operating at a frequency of 110 GHz. The experimental setup involves a semiconductor wafer (silicon or gallium arsenide), which is irradiated by a laser beam. As a result of the irradiation, plasma is created inside the silicon which reflects the microwaves produced by the gyrotron for as long as the laser pulse continues. The reflected high-frequency and short-pulse gyrotron radiation (chopped to 10 ns simply by turning on and off the laser)) can then be directed towards a high-frequency, high-gradient accelerating structure. It has been observed, however, that only 70 percent of the radiation is reflected while the rest 30 percent is absorbed or pass through the silicon wafer. More importantly, it has been found that an increase of the gyrotron output power toward megawatt levels leads to an increase of the reflection as well reaching 80-85 percent. In this laser-driven semiconductor switch (LDSS) the photoconductivity was induced in the wafers using a 532 nm laser, which produced 6 ns, 230 mJ pulses. Using two active wafers, pulses of variable length down to 3 ns duration were created. The switch was tested at incident 110 GHz RF power levels up to 600 kW.

The Plasma Science and Fusion Center (PSFC) at MIT is collaborating with a group from Stanford University that designs accelerator cavities, which can now be tested with the “Megawatt Microwave Pulse Chopper.”

Source: MIT News

Novel Highly Sensitive Diode which Converts Microwaves to Electricity

Recently, the Japan Science and Technology Agency (JST), Fujitsu Limited, and the Tokyo Metropolitan University developed a highly sensitive new rectifying element in the form of a nanowire backward diode which can covert low-power microwaves into electricity. It is expected that such devices can be used for harvesting energy from the ambient radio waves in the environment such as, for example, that are produced by the mobile base stations and wireless networks. This is important for building networks of sensors for IoT that do not require batteries. The selectivity of this novel nanowire backward diode is more than one order of magnitude higher than that of the available Schottky barrier diodes. This technology allows converting weak microwaves (with power as low as 100 nW) to electricity. The backward diode is formed by joining two different types of semiconductors and operate on a principle that involves the tunnel effect. It is characterized by steep rectification at zero bias. The experiments carried out at a frequency of 2.4 GHz (which is widely used in the contemporary 4G LTE and Wi-Fi communications) have demonstrated a sensitivity of 700 kV/W. This value is more than 10 times higher than the sensitivity of the conventional Schottkiy barrier diode, which amounts to only 60KV/W.

Source: ACN Newswire

A New Way to Convert Heat to Electricity

The discovery made by an international team of researchers from China and the USA has been published in the journal Science Advances. It is considered a promising new way to provide more efficient energy generation from heat in various instances like car exhaust, interplanetary space probes, and industrial processes. The discovery is based on quasi particles called paramagnons. Paramagnons are magnons (a collective excitation of the electrons' spin structure in a crystal lattice) in magnetic materials which are in their high temperature, disordered (paramagnetic) phase. In such state, the flux of their spins give rise to an effect known as magnon-drag thermoelectricity. The essence of this effect is that when one side of a magnet is heated, the magnetism in the colder side increases and drags the electrons creating electricity.

Source: Science Advances and Technology.Org

Magnetization of non-magnetic metals by laser light

Physicists from Nanyang Technological University, Singapore (NTU Singapore) and the Niels Bohr Institute in Copenhagen, Denmark, have developed a method to turn a non-magnetic metal into a magnet using laser light. They have found that when the light irradiation is strong enough, the plasmons in a non-magnetic metallic disk can spontaneously rotate in either a left-handed or right-handed fashion, even when driven by linearly polarised light. According to their work, when a plasmon's strong internal fields modify a material's electronic band structure it transforms also the plasmon as well, creating a feedback loop enabling the plasmon to exhibit spontaneously a chirality. It is namely this chiral motion of the plasmon that produces a magnetization which then made the non-ferrous metallic disk magnetic.

Source: Phys Org