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# Optically and magnetically controlled meta-dipoles on microwaves

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Optically and magnetically controlled half-wave meta-dipoles, which are mini-resonators based on a copper multi-pass chiral spiral containing paired cores, were proposed, performed and experimentally investigated in the range of 3−12 GHz in the conditions of rectangular waveguides and free space, representing mini-resonators based on a copper multi-pass chiral spiral containing paired cores: GaAs semiconductor as an optical control element and ferrite as a magnetic element. The dynamics of the resonant responses of reflection and transmission of microwaves was measured during photoexcitation of a semiconductor (fiber-optically 0.97 $\mu$m or at a distance of 0.53 $\mu$m with a laser pointer) and during excitation of ferromagnetic resonance (FMR) in ferrite in the presence of constant magnetic field $H_0$. It is shown that with meta-dipoles, the transformation of responses under external influence is observed and the possibility of independent control of the frequency and intensity of resonances appears, which is in demand in telecommunication microwave devices.

**Keywords:** half-wave meta-dipole, chiral multi-pass spiral, semiconductor, ferrite, fiber-optic and magnetic control, microwaves, coupled ferromagnetic and dipole resonances.

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## 1. Introduction

Currently, there is still interest in metamaterials containing electrically conductive chiral open elements, for example, various volumetric spirals, planar open rings with small dimensions compared to the wavelength, having spatial dispersion in the absence of central symmetry [1,2], since they are compatible with elements of electrical, magnetic, and optical control and they allow using fairly simple means in a wide range of frequencies to form different resonant electromagnetic properties due not to chemical composition, but to geometry and size, and to control the properties. For this purpose electrodynamic objects are combined in metastructures with objects with other interesting properties controlled by external factors, such as electric voltage, magnetic field, or optical radiation. The phenomenological theory of chiral media is based on material equations, which, in addition to dielectric and magnetic permeability, contain a chirality parameter that characterizes the relationship of electric induction with a magnetic field and magnetic induction with an electric field. This means that the current induced by an alternating magnetic field in chiral elements causes not only a magnetic dipole moment, but also an electric one, and an alternating electric field induces a current in such elements, which creates both electric and magnetic dipole moments. The directions of the moments are related to the direction of the spiral [1,2].

The electrical control using varactors is most often used in metastructures, since they are simply integrated into many types of metamaterials [3–5]. It is known that the resonant frequency can be shifted by applying a reverse bias voltage to varactors. Limitations of the universal use of varactors include losses at low levels of electrical voltage and reduced efficiency at high frequencies (above 4−10 GHz).

Combinations with ferrite are used for magnetic control by exciting ferromagnetic resonance (FMR) in ferrite by applying a permanent magnetic field $H_0$ and shifting the resonant frequency with a change $H_0$ [6–8]. Difficulties arise at high frequencies due to the need to use large magnetic fields or materials with large internal fields, such as hexaferrites.

Special attention is paid to optical control using semiconductors as controls [9–14], which is attractive because of its low sensitivity to electromagnetic interference, good isolation between signal and control channels, high speed and the possibility of fiber-optic targeted effects on the resonance intensity of individual elements in a wide range of microwave and terahertz frequencies. Optical exposure does not change the frequency of resonant responses, unlike electric and magnetic ones.

Reconfigurable and tunable metamaterial technology and possible applications are covered in Refs. [15–17]. A number of papers discuss the possibility of practical application of metastructures, meta-atoms, and meta-surfaces in a variety of microwave devices, among which tunable filters and antennas occupy an important place [3,15–18], for which independent control of amplitude, frequency, and width within an individual resonant band is relevant, but currently unresolved. In this regard, both new structures and the development of management methods are in demand, which is an incentive and a goal for further research.

The purpose of our paper is to implement and experimentally study new functional metastructures and new control methods for the development of an element base in microelectronics related to the problems of transmitting, receiving and converting information using microwave waves.

This paper for the first time implements and studies upgraded half-wave metadipoles, which are a chiral multi-input copper spiral containing paired cores: GaAs semiconductor (as an optical control element) and iron-yttrium ferrite (a magnetic control element). The dynamics of the resonant responses of microwave transmission and reflection in the range of 3–12 GHz (under conditions of rectangular waveguides and free space) under external magnetic and optical influences has been experimentally studied. An interesting functionality of magneto-optical control in metadipoles has been revealed based on the experiments conducted, for example, it has been shown that under certain conditions, when coupled ferromagnetic and dipole resonances interact, the frequency of the dipole resonance (DR) can be shifted by a magnetic field $H_0$, and the depth and width of the ferromagnetic resonance (FMR) can be changed by optical irradiation.

The results obtained are related to controlled meta-microelectronics („photomagnetic metamicroelectronics"), based on optical and magnetic methods for controlling the propagation of microwaves, in contrast to radiophotonics, nanophotonics, nanoplasmonics, magneto-optics, studying the control of the propagation of optical signals [19–21].

## 2. Studied metadipoles. Experimental methodology

Figure 1 shows photos of some experimental samples of methadipoles studied in the range of 3–12 GHz: optically controlled (methadipole I) are mini-resonators based on a multi-input copper spiral containing a GaAs semiconductor core and magnetically-optically controlled (methadipole II) containing paired cores — semiconductor GaAs as an optical control element and iron-lithium ferrite as a magnetic control element.

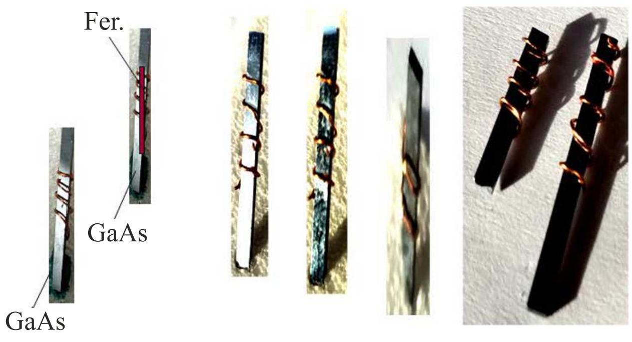


**Figure 1.** Images of the studied metadipoles: metadipole I with a GaAs semiconductor core, metadipole II contains paired cores — semiconductor GaAs and ferrite Fer, and a number of metadipoles with different spiral lengths and number of revolutions.

The samples of the metadipole I are made by winding a spiral with a copper wire with a diameter of 0.3 mm around a GaAs semiconductor core. The samples of methadipole II were obtained by winding a spiral around paired (glued to each other) cores. The pitch of the spiral was approximately 2 mm. Several samples with different lengths of copper wire at different revolutions (from 1.5 to 4) were implemented to observe resonant responses at different frequencies within a given range and clarify functional patterns which differed respectively, in different spiral heights and different resonant frequencies. GaAs samples with a cross-section of $2 \times 1$ mm and a length of 7 to 23 mm were used, ferrite core samples also had the same cross-section of $1 \times 0.9$ mm, and their lengths varied from 5 to 7 mm.

The responses of microwave transmission $T$ and reflection $R$ were measured under external optical and magnetic influence on the metadipole in the range of 3–6 GHz using a panoramic VSWR meter P2-58 under rectangular waveguide conditions (cross section $48 \times 24$ mm) and free space (in the waveguide gap), as well as with a panoramic VSWR meter P2-61 in the range of 8–12 GHz (waveguide cross section of $23 \times 11$ mm). The experimental scheme for measuring $T$ and $R$ is shown in Figure 2, *a* and 2, *b*.

The dynamics of resonant responses has been studied, which depends on the properties of the photoinduced dielectric constant GaAs, the magnetic permeability of ferrite upon excitation of ferromagnetic resonance, and the coupling of a metadipole with a waveguide.

For optical control, fiber-optic irradiation with a laser diode with a power of $P_\lambda$ in continuous mode ($\lambda = 0.97\,\mu$m) was used. It was possible to change the power $P_\lambda$ measured by Laser Power Meter (Field Max, COHERENT company) within 0–1000 mW by changing the current. The semiconductor was photo-excited by applying an optical fiber (diameter $110\,\mu$m) perpendicular to its surface from above from the end side or from the side at a distance of about a few millimeters. At the same time, the GaAs sample was partially exposed to optical effects depending on its size, since the light radiation had the shape of a circle with a diameter of about 5 mm, at the same time, a fraction of the radiated power could pass by the sample, as evidenced by the visualization of infrared irradiation with a laser visualizer.

A standard laser pointer 303 Lxi ($P_\lambda = 60$ mW, $\lambda = 0.53\,\mu$m) was also used at a distance of several meters from the dipole to irradiate GaAs with green light to determine control capabilities at different $\lambda$, with low powers, in different conditions by generally available relatively cheap means.

The studies were conducted at room temperature under conditions necessary for GaAs photoexcitation, when the photon energy $h\nu$ is higher than the band gap $E_g = 1.42$ eV [$h\nu$ ($\lambda = 0.53\,\mu$m) $> E_g$] or close to the band gap at $\lambda = 0.97\,\mu$m [22].

An electromagnet was used for magnetic action in the case of waveguides, and a disk magnet *3* was used in conditions of free space. The magnitude of the permanent

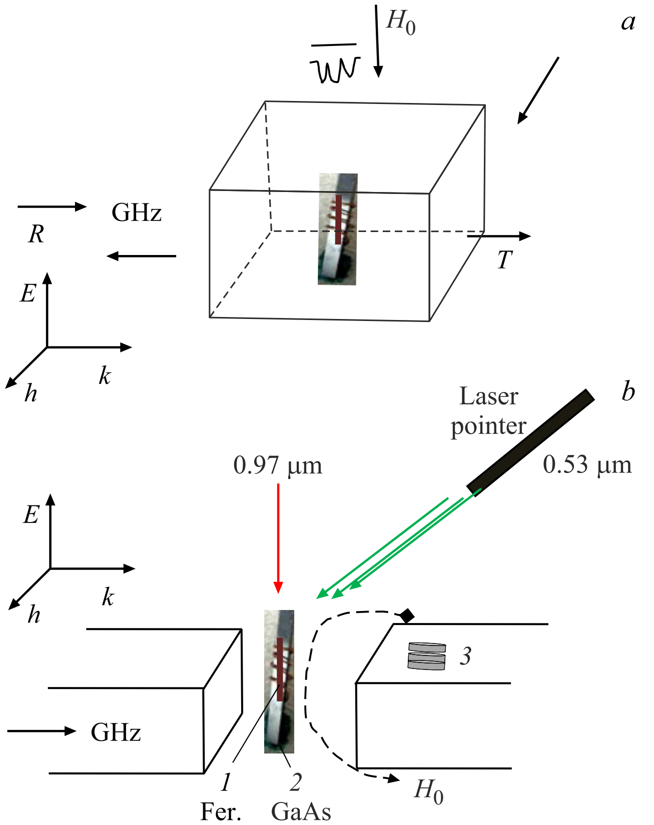


**Figure 2.** Scheme of measurements of the frequency dependence of the transmission coefficients $T$ and reflection $R$ of microwaves with meta-dipoles: $a$ — under the conditions of a waveguide in an electromagnet when a permanent magnetic field is applied $H_0$, a wavy line with line — symbol of the electromagnet; $b$ — in conditions of free space when $H_0$ (disc magnet *3*, the dotted line corresponds to the direction $H_0$) and fiber-optic irradiation ($0.97\,\mu$m) or with a laser pointer ($0.53\,\mu$m).

magnetic field $H_0$ depended on the distance between *3* and ferrite (Figure 2, $a$ and 2, $b$).

When studying the possibility of control, the features of resonant effects in the elements of the metadipoles were taken into account, which manifested themselves in the measured responses $T$ and $R$. By analogy with chiral means based on open spirals, [2,23] with methadipole I (or methadipole II in the absence of external magnetic action), a dipole resonance was observed, excited by an alternating electric field, which induces a resonant current in the spiral, causing both electric and magnetic dipole moments. The intensity of DR changes under the optical irradiation with a change of the photoinduced dielectric constant of the semiconductor.

Resonant interactions can be excited in the ferrite in metadipole II along with DR, when a permanent magnetic field $H_0$ is applied, which, by analogy with chiral ferrite media [24], can be of two types. One of them, ferromagnetic resonance (FMR), is the result of the resonant interaction of ferrite with the microwave field $h$ ($H_0 \perp h$), and can be excited in free ferrite. It is known that FMR shifts towards high frequencies with an increase of the value of $H_0$. Another type, let's call it a chiral ferromagnetic resonance (−ChFMR), is excited only at frequencies of metadipole DR, and it is caused by the resonant interaction of magnetized ferrite with an induced alternating magnetic moment and is controlled by the field $H_{0\perp}$ of induced magnetic moment (spiral axis). ChFMR is not excited in free ferrite or in ferrite outside the spiral.

## 3. Dynamics of resonant responses of microwave transmission and reflection under external influence

The frequency dependence of the coefficients of transmission $T$ and reflection $R$ of microwaves in the GHz range was measured with the arrangement of metadipoles along the axis of rectangular waveguides or in free space. Resonant minima $T$ were observed in dependencies, which correspond to resonant maxima $R$ (DR dipole resonances excited by a microwave electric field $E$ in a spiral both in the absence of cores and with cores) under optical exposure conditions (Figure 3, $a$ and 3, $b$), magnetic upon excitation of ferromagnetic resonance (Figure 4, $a$–$c$), chiral-ferromagnetic resonance (Figure 5, $a$ and 5, $b$), as well as when combining magnetic and optical external impacts (Figure 6, $a$ and 6, $b$).

### 3.1. Optical control: metadipole $I$, $P_\lambda$ ($\lambda = 0.97\,\mu$m), $H_0 = 0$

Figure 3, $a$ demonstrates the dynamics of the resonant response of transmission $T$ of microwaves with a metadipole I in free space, reflecting the behavior of DR. It can be seen that $T$ increases at the resonant frequency with an increase of the fiber-optic irradiation power $P_\lambda$ approaching the transparency level of the frequency domain outside of resonance. This is quite expected, given the increase of the imaginary part of the dielectric constant of GaAs on microwaves during photoexcitation [25].

The response $T$ in free space with two metadipoles I, differing in the length of the spiral wire (dipole resonances DR1 and DR2 manifest themselves at different frequencies), located at a distance of several millimeters from each other along the axis of the waveguide, is shown in Figure 3, $b$. It can be seen that the alternating targeted effect of $P_\lambda$ on each of the meta-fields leads to a change in the corresponding DR almost to the level of transparency: DR1 disappears when the first dipole is irradiated while DR2 does not disappear (curve *1′*), respectively, DR2 disappears when the second dipole is irradiated while DR1 does not disappear (curve *2′*).

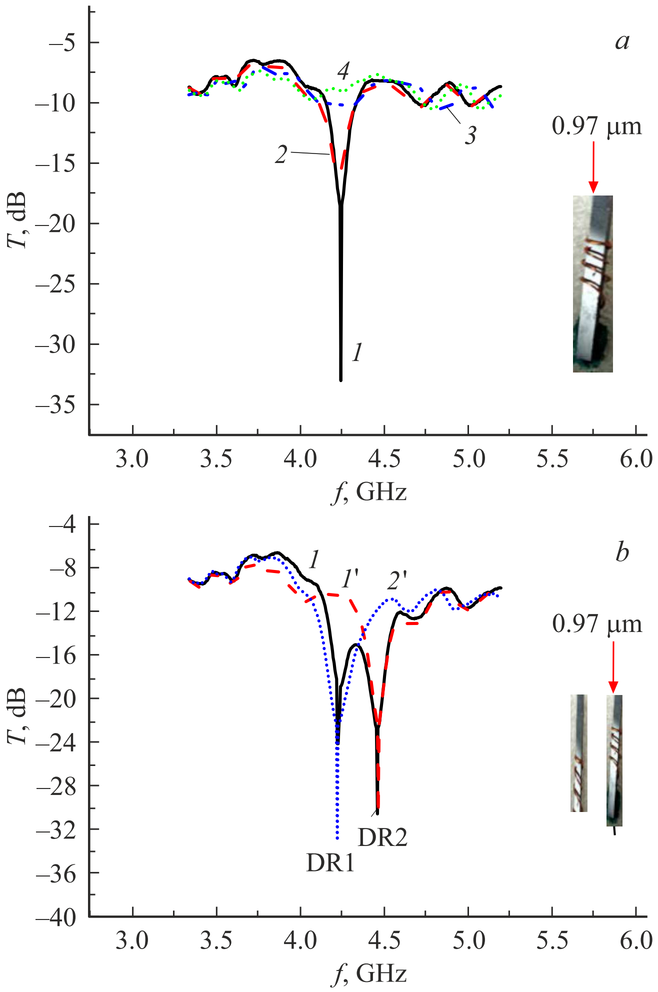


**Figure 3.** Measured dynamics of the resonant response of transmission $T$ of microwaves with a metadipole I in free space in the absence of magnetic influence when changing the power of fiber-optic irradiation 0.97 $\mu$m, $P_\lambda$, mW: *a* — with one metadipole, 0 (*1*), 60 (*2*), 100 (*3*), 120 (*4*); *b* — with two metadipoles, 0 (*1*), 120 (*1'*), 120 (*2'*).

### 3.2. Magnetic control: metadipole II, $P_\lambda = 0$, FMR: $H_0 \perp h$

Figure 4, *a–c* shows the dynamics of the responses of microwaves transmission $T$ and reflection $R$ in rectangular waveguides in case of a ferromagnetic resonance excitation in the absence of optical impact ($P_\lambda = 0$) with metadipole II: a spiral with approximately 4 turns (Figure 4, *a*), a spiral with 3 (Figure 4, *b* and 4 turns, *c*).

The results of measurement of $T$ in the range of 3–6 GHz with metadipole II based on a spiral with approximately 4 turns are shown in Figure 4, *a*. For $H_0 = 0$ (curve *1*), we observe that: $DR_0$ (frequency $f = 4.35$ GHz, depth −26 dB).

The frequency of DR slightly shifts (towards low frequencies) in case of magnetization of ferrite ($H_0 = 200$ Oe) and FMR excitation at some distance from the frequency of $DR_0$, when a change of magnetic permeability extends to the frequency domain of $DR_0$, and the depth increases which is associated with the effect of FMR and a change of the coupling of the metadipole with the waveguide (curve *2*), while FMR is not noticeable in the spectrum $T$, as in a free ferrite core or in ferrite located outside the spiral. The FMR intensity increases (the resonance depth increases, $T$ decreases at the resonant frequency) with a further increase of $H_0$ and the FMR frequency approaches the $DR_0$, while the DR narrows and weakens, shifting to high frequencies.

Two resonances are observed at $H_0 = 1200$ Oe (curve *3*): low-frequency FMR (frequency 4.22 GHz, depth — 15 dB) and high-frequency DR (4.4 GHz, −23 dB). The further increase of $H_0$ is accompanied by the dynamics characteristic of associated resonances with energy transfer and transition from one resonance to another.

The high-frequency resonance, transforming into FMR, is excited outside the studied range at $H_0 = 1600$ Oe, while a low-frequency peak remains in the spectrum $T$, as the DR, which approaches the state of $DR_0$ (curve *4*).

A similar dynamic characteristic of coupled resonances is observed with different metadipoles in different frequency ranges at other values of $H_0$. The manifestation of coupled resonances of different nature (ferromagnetic and dipole) is observed for the first time in the spectrum $T$. We are not aware of any study where related FMR and DR have been observed or used.

The results of measurements of $T$ and $R$ in the range of 8–12 GHz with metadipole II based on a spiral of about 3 turn are shown in Figures 4, *b* and 4, *c*.

We observe $DR_0$ (9.86 GHz, −21 dB) in Figure 4, *b* in the spectrum $T$ at $H_0 = 0$, curve *1*. FMR (8.84 GHz, −4.3 dB) is excited with the superposition of $H_0 = 2300$ Oe, while the state of the DR changes, a frequency shift to 10.04 GHz and an increase of depth to −29 dB is visible (curve *2*).

We observe two resonances with an increase of $H_0 = 2500$ Oe (curve *3*): low-frequency FMR (9.49 GHz. −7.5 dB) and high-frequency DR (10.42 GHz, −14 dB). A further increase of $H_0 = 2800$ Oe leads to an increase and a shift of FMR, a shift and a weakening of DR (curve *4*). DR transforms into FMR in field $H_0 = 3400$ Oe (curve *5*) and moves away towards high frequencies to $f = 11.65$ GHz, low frequency resonance (9.87 GHz, −15.2 dB), as DR approaches the initial state of $DR_0$.

We observe $DR_0$ in Figure 4, *c* in the spectrum $R$ at $H_0 = 0$ as a maximum at a frequency of $f = 9.8$ GHz, corresponding to the minimum $T$, and a resonant minimum (−16 dB) at a frequency of $f = 10.05$ GHz: $DR_0$ (10.05 GHz, −16 dB).

When $H_0 = 2500$ Oe (curve *2*) is superimposed with FMR excitation (8.7 GHz, −8.1 dB) dipole resonance (10.13 GHz, −17 dB) shifts to high frequencies relative to $DR_0$. When $H_0$ increases to 2800 Oe (curve *3*) FMR (9.38 GHz, −6.7 dB) is observed along with DR (10.21 GHz, −13.9 dB), which has shifted towards high

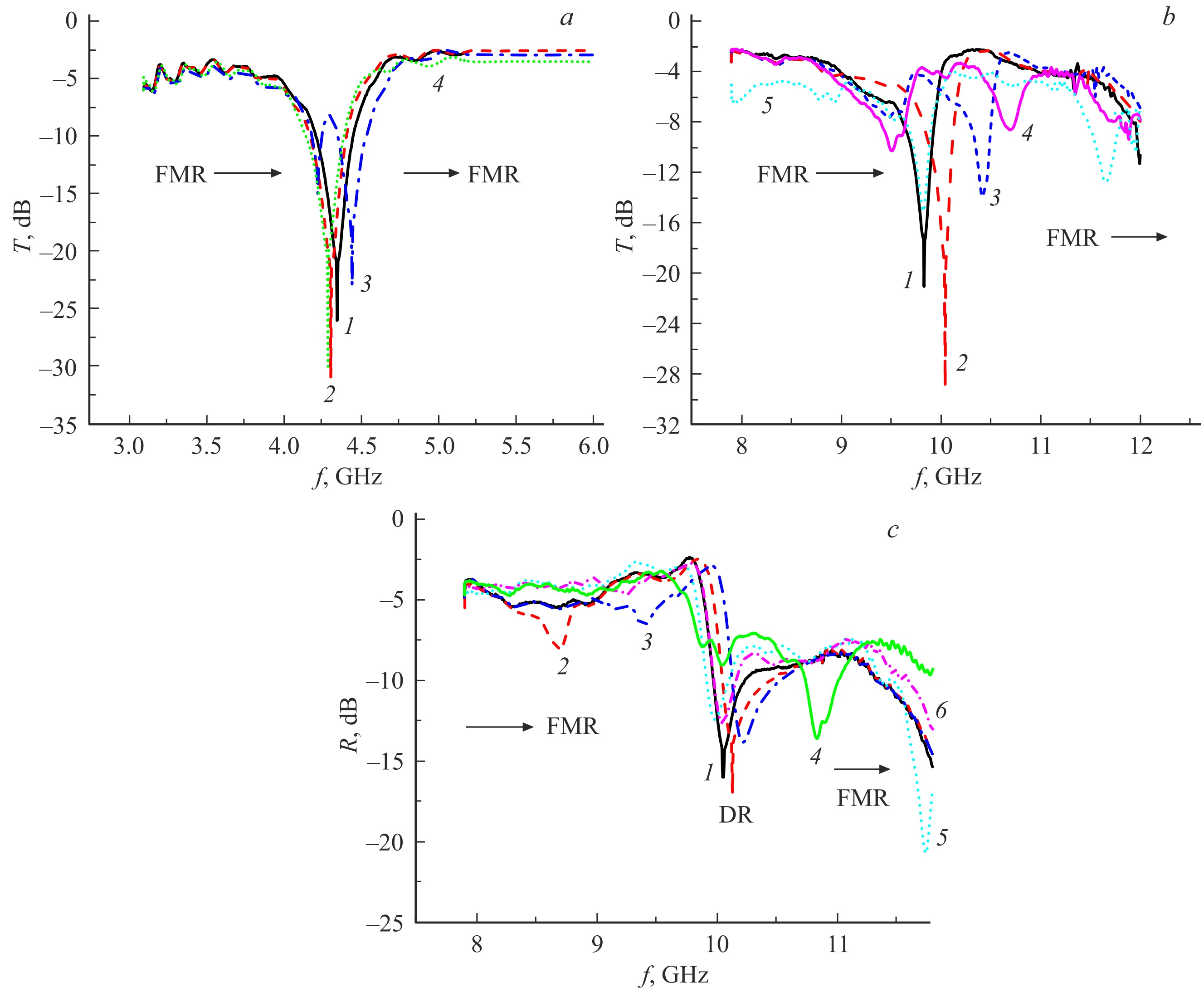


**Figure 4.** Measured dynamics of the frequency dependences of transmission $T$ and reflection $R$ of microwaves with metadipoles II in rectangular waveguides in the absence of optical action when FMR is excited near DR with a change $H_0$: *a* — $T$ in the range 3–6 GHz, $H = 0$ (*1*), 200 (*2*), 1200 (*3*), 1600 Oe (*4*); *b* — $T$ in the range 8–12 GHz, $H = 0$ (*1*), 2300 (*2*), 2500 (*3*), 2800 (*4*), 3400 Oe (*5*); *c* — R in the range 8–12 GHz, $H = 0$ (*1*), 2500 (*2*), 2800 (*3*), 3400 (*4*), 4000 (*5*), 4400 Oe (*6*).

frequencies under the impact of FMR. We observe low-frequency and high-frequency resonant minima (curve *4*) at frequencies of $f = 10.1$ GHz and $f = 10.8$ GHz at $H_0 = 3400$ Oe. Transformation of low-frequency and high-frequency peaks takes place in the fields $H_0 = 4000$ Oe (curve *5*) and 4400 Oe (curve *6*), the high-frequency peak, like FMR, moves outside the studied range, and the low-frequency peak, like DR (9.99 GHz, −12 dB) and DR (10 GHz, −12 dB) approach the initial state of $DR_0$.

### 3.3. Magnetic control: metadipole II, $P_\lambda = 0$, ChFMR: $H_0 \perp$ spiral axes

Figure 5, *a* and 5, *b* show the dynamics of the responses of transmission $T$ and reflection $R$ of microwaves with metadipole II in a rectangular waveguide in the range of 8–12 GHz at $P_\lambda = 0$ in conditions when the constant magnetic field is perpendicular to the axis of the spiral with ChFMR excitation.

We see $DR_0$ (9.8 GHz, −14 dB) in Figure 5, *a* in the spectrum $T$ in the absence of $H_0$ (curve *1*). $DR_0$ slightly changes at $H_0 = 2700$ and 3400 Oe (curves *2* and *3*). Two resonances are observed in the fields $H_0 = 3700$, 4000, 4170 and 4000 Oe (curves *4*–*7*): a low-frequency resonance caused by ChFMR, and a high-frequency resonance with energy transfer and transformation of resonances when $H_0$ changes. ChFMR does not appear in the spectrum $T$ with an increase of $H_0 = 5000$ Oe, since it is excited only at the resonant frequency of the metadipole at lower values of $H_0$; in this case, we observe only low-frequency resonance as DR (9.7 GHz, −16 dB), approaching the initial state of $DR_0$ (curve *8*).

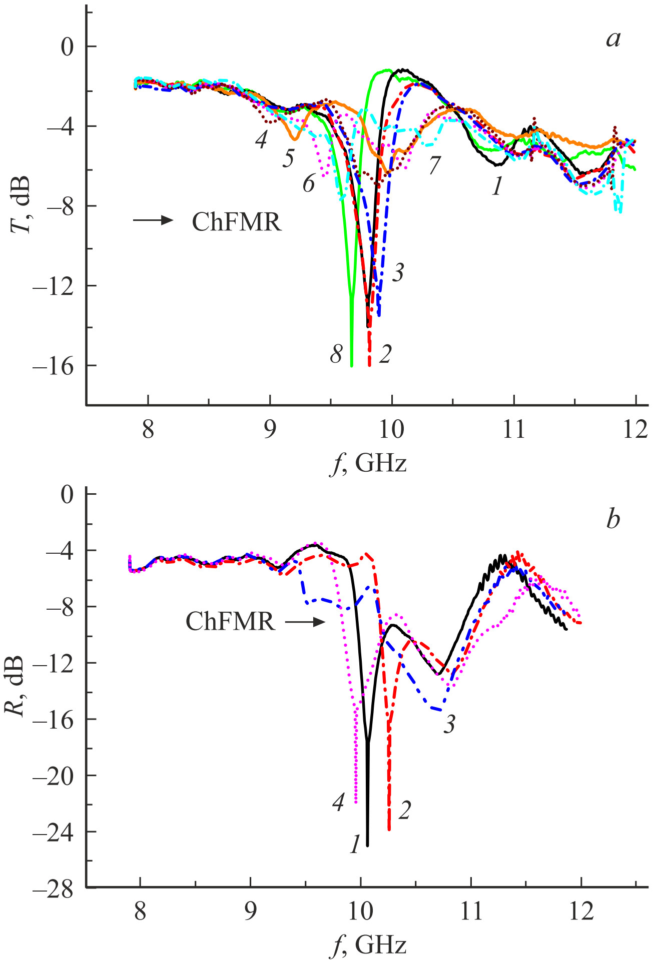


**Figure 5.** Measured dynamics of the frequency dependences of microwave transmission $T$ ($a$) and reflection $R$ ($b$) with metadipole II in a waveguide in the range of 8–12 GHz in the absence of optical action in case of ChFMR excitation with a change of $H_0$, Oe: $a$ — 0 (*1*), 2700 (*2*), 3400 (*3*), 3700 (*4*), 4000 (*5*), 4170 (*6*), 4400 (*7*), 5000 (*8*); $b$ — 0(1), 3700 (*2*), 4000 (*3*), 5000 (*4*).

It can be seen in Figure 5, $b$ that $DR_0$ (10.06 GHz, −25 dB) appears in the spectrum $R$ in the absence of $H_0$ (curve *1*). Low-frequency ChFMR (9.3 GHz, −5.6 dB) and high-frequency DR (10.25 GHz, −24 dB) are observed in the field $H_0 = 3700$ Oe (curve *2*) and then the energy transfer and transformation of low-frequency ChFMR (9.56 GHz, −7.8 dB) and high-frequency DR (10.7 GHz, −15.4 dB) with an increase of $H_0$ to 4000 Oe (curve *3*).

When $H_0$ increases to 5000 Oe (curve *4*), the low-frequency resonance as DR (9.95 GHz, −22 dB) approaches the initial state of $DR_0$, and high-frequency resonance as ChFMR (10.83 GHz, −13.6 dB), excited only at the frequencies of the metadipole, does not appear in the spectrum $R$ with a further increase of $H_0$, which corresponds to the results of measurements of the dynamics of the spectrum $T$ (Figure 5, $a$).

### 3.4. Magneto-optical control: metadipole II, $H_0$, $P_\lambda$, $\lambda = 0.97\ (0.53)\ \mu$m

It follows from Sections 3.2 and 3.3 that the application of a constant magnetic field $H_0$ can easily establish a coupled resonance mode by exciting ferromagnetic and chiral-ferromagnetic resonances at frequencies near the dipole resonance.

The measurements in free space in the range of 3–6GHz can show that optical irradiation affects not only the dipole resonance, as shown in Section 3.1, but also FMR and ChFMR when they are excited in the mode of coupled FMR and DR resonances (Figure 6, $a$ and 6, $b$).

The resonant response of $DR_0$ (3.61 GHz, −12.4 dB) in the spectrum $T$ in the absence of $H_0$ is seen in Figure 6, $a$, curve *1*. FMR (3.17 GHz, −15 dB) appears in the field $H_0 = H_1 \cong 150$ Oe along with DR (3.56 GHz, −25 dB), curve *2*.

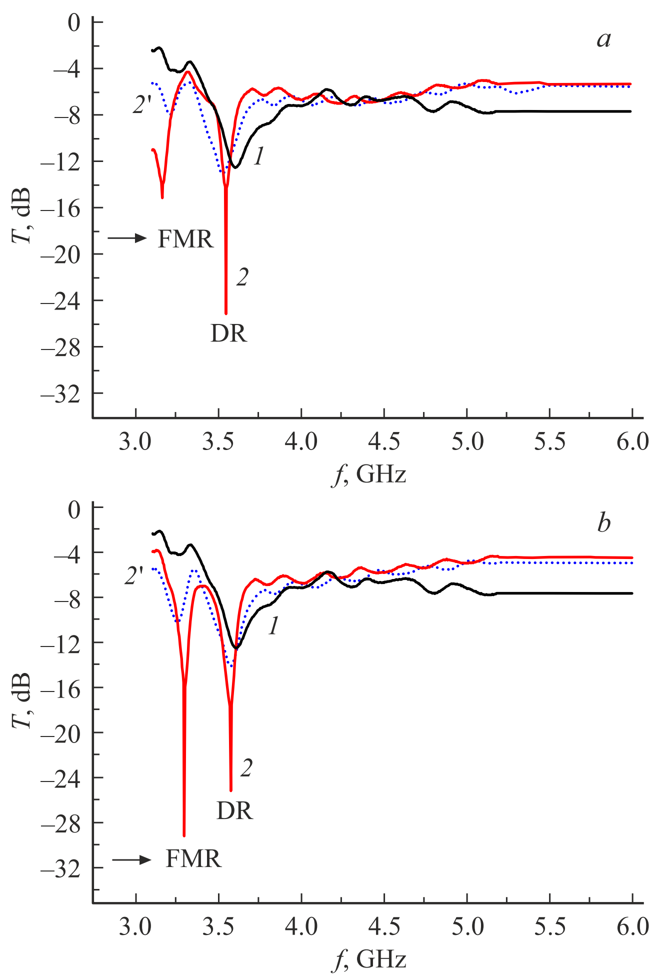


**Figure 6.** Measured dynamics of frequency dependences of microwave transmission $T$ with a meta-dipole II in free space in the range of 3–6 GHz in the mode of coupled FMR and DR with 0.97 (053) $\mu$m irradiation: $a$ — *1*($H_0 = 0$ Oe, $P_\lambda = 0$ mW), *2* ($H_0 = 150$ Oe, $P_\lambda = 0$ mW), *2′* ($H_0 = 150$ Oe, $P_\lambda = 60$ mW); $b$ — *1* ($H_0 = 0$ Oe, $P_\lambda = 0$ mW), *2* ($H_0 = 200$ Oe, $P_\lambda = 0$ mW), *2′* ($H_0 = 200$ Oe, $P_\lambda = 60$ mW).

The frequency shift of DR and the increase of intensity relative to $DR_0$ observed on the curve *2* (Figure 6, *a*) are associated with the effect of FMR and the establishment of optimal coupling of the meta-dipole with the supply line with an increase of absorption in ferrite. 0.53 (0.97) $\mu$m optical irradiation with power of $P_\lambda = 60$ mW (curve *2′*) attenuates the intensity of both DR(3.53 GHz, −12.9 dB) and FMR (3.2 GHz, −7.86 dB) in the presence of $H_0 = H_1 = 150$ Oe: the depth of the resonant minima of both resonances decreases, practically without shifting their frequencies.

Figure 6, *b* (curve *2*) shows a frequency shift and FMR amplification (3.3 GHz, −29 dB) along with a shift of frequency of DR (3.58 GHz, −23 dB) in the absence of $P_\lambda$ with an increase of $H_0 = H_2$ to 200 Oe and the approach of the ferromagnetic resonance FMR to the frequency of the dipole $DR_0$. 0.53 (0.97)$\mu$m optical irradiation ($P_\lambda = 60$ mW) attenuates the intensity of both resonances when $H_2$ is applied (curve *2′*): FMR (3.27 GHz, −10.14 dB) and DR (3.57 GHz, −13.96 dB).

Thus, in the mode of coupled FMR and DR resonances, it becomes possible to independently control the resonant frequencies by a magnetic field $H_0$ and the resonance intensities by optical irradiation $P_\lambda$ with sequential exposure of metadipole to magnetic field and optical irradiation.

## Conclusion

Optically magnetically controlled metadipoles comprising mini-resonators based on a copper multipass chiral spiral containing paired cores of GaAs semiconductor and iron-yttrium ferrite, have been proposed and performed for the first time.

The characteristics of dipole resonance, ferromagnetic and chiral-ferromagnetic resonances observed with metadipoles in the range of 3−12GHz with a superimposed constant magnetic field and fiber-optic 0.97 $\mu$m irradiation are studied by measuring the dynamics of the resonant responses of the transmission and reflection of microwaves in rectangular waveguides and free space with a power variation from 0 to 120 mW, as well as with irradiation by 0.53 $\mu$m laser pointer with a power of 60 mW applied at a distance of several meters from the dipoles.

Measurements of the microwave transmission spectrum with two metadipoles show the targeted effect of optical irradiation, when the intensity of the dipole resonance of a given metadipole attenuates, the resonant properties disappear.

It is shown that ferromagnetic resonance increases as it approaches the frequency of dipole resonance and can be controlled not only by a permanent magnetic field $H_0$, but also by optical irradiation with GaAs, and dipole resonance can be controlled not only by optical irradiation, but also by the field $H_0$.

It is shown that in the mode of coupled ferromagnetic (chiral-ferromagnetic) and dipole resonances, it becomes possible to independently control the resonant frequencies by a magnetic field $H_0$ and the resonance intensities can be controlled by optical irradiation with sequential exposure of metadipole to magnetic field and optical irradiation. Coupled resonances of different nature (ferromagnetic and dipole) are studied for the first time.

The results obtained are based on the combination of optical and magnetic methods for controlling the propagation of microwaves within the framework of currently in demand controlled meta-microelectronics and can be useful, in particular, for the development of filters, microwave antennas in satellite communication systems, radar, telecommunication devices.

### Conflict of interest

The authors declare that they have no conflict of interest.

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