Novel conception of the terahertz-range spectrometer based on Fabry-Perot interferometer

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***Abstract*—we have developed novel THz spectrometer based on Fabry-Perot interferometer. The novelty of the device is related to the metal-covered high-resistivity silicon mirrors. Also an original body of mathematics which allows broadband incident signal spectrum reconstruction was elaborated.**

I. Introduction And Background

THz-range Fabry-Perot interferometer (FPI) is the well-known object [1, 2]. This device is commonly used in scientific laboratories for the experiments usually related to astrophysics. Golay cell or pyroelectric were usually used as signal detectors. To date there are some ideas to use this device as simple THz-spectrometer [3]. Nevertheless, this device has an imperfection - it is usually applicable to narrow-band spectral lines with the known wavelength detection.

Our novel interferometer has some features. At first, the original body of mathematics allows one to calculate the spectrum and the form of the signal falling into FPI, with use of the measured device response. At second, we used the pair of high-resistivity Cr-coated HRFZ-Si as the mirrors of FPI. The advantage of Si is more simple production and also the possibility to cover the all THz spectral region (30-3000 micron) with only one pair of mirrors. Also the well-known metal meshes [1–3] were used as the mirrors and tested. The testing of all the types of the mirrors was performed with use of Fourier spectrometer in THz range.

II. Results

We have assembled FPI based on the plane-parallel HRFZ-Si plates 1.5 mm thick, Cr-coated with Cr thickness 5 nm. Since the transmission of such mirrors is ~ 25% and does not change throughout the operating range, FPI, consisting of a pair of such plates, covers entire terahertz range (see Fig., where FPI transmission spectrum for the spacing 210 micron between the mirrors is shown). Also, we have developed FPI based on metallic meshes. The meshes were also developed in house. It is possible to cover entire terahertz range with two pairs of grids with different values of the holes. Characteristic value of the finesse for the region 30-300 micron is about 10, and for the region 300 micron and farther is about 7. These values are usual for such objects. The finesse of the FPI based on the plane-parallel HRFZ-Si plates, determined experimentally, is equal to 5-8, depending on the wavelength, which corresponds to the theoretical values for the mirror reflectance R about 0.55 and higher. To restore the spectrum of the signal incident on the FPI, algorithms for the linear algebraic equations system (LAES) $Au=f$ were used. The system is derived from the construction of the discrete model. The perturbations of the right side of the system are random and distributed as $(0,\ \delta^2)$. Stable solution for û is the solution of the problem, where α> 0 is regularization parameter and represents the discrete differential operator of order 1. This solution is defined as the solution of $\min_{u\in R^2}\left\{\left\|Au-\bar{f}\right\|_2^2-\alpha^2\left\|Lu\right\|_2^2\right\}$, where $\alpha>0$ – regularization parameter, which was chosen with use of semi-heuristic method based on the matrix A spectrum and the level of the perturbations in f. $L\in R^{(n-1)\times n}$ – a discrete differential operator of the 1st order. The solution for $\hat{u}$ is equivalent to the solution of the problem of calculating the normal pseudo-solution

$$\min_{u\in R^2}\left\|\begin{pmatrix}A\\ \alpha L\end{pmatrix}u-\begin{pmatrix}\bar{f}\\ 0\end{pmatrix}\right\|_2,\ \hat{u}=\begin{pmatrix}A\\ \alpha L\end{pmatrix}^{+}\bar{f}\,. \quad (1)$$

Using the method of enhanced systems, the solution of (1) is determined by solving LAES with use of the orthogonal Gaussian elimination. Suggested algorithm can obtain stable regularized solution of the relative level of disturbances in the measurements below 5%. The required number of measurements should be ≥ 50.

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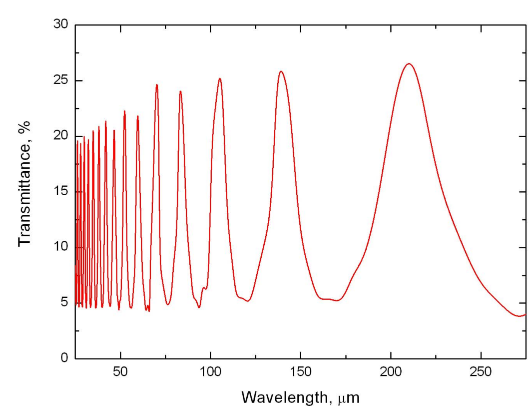

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