UDC 621.396.946

ON ONE POSSIBILITY OF CONSTRUCTING BAND-PASS FILTERS BASED ON OPTICAL MICRO-RESONATORS WITH WHISPERING GALLERY OSCILLATIONS

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ОДНА З МОЖЛИВОСТЕЙ ПОБУДОВИ СМУГОВИХ ФІЛЬТРІВ НА ОСНОВІ ОПТИЧНИХ МІКРОРЕЗОНАТОРІВ З КОЛИВАННЯМИ ШЕПОЧУЧОЇ ГАЛЕРЕЇ

Пропонується нове рішення задачі побудови смугових фільтрів за допомогою використання спеціальним чином оптимізованих режекторних структур, побудованих на оптичних микрорезонаторах з коливаннями шепочучої галереї. Показано, що за допомогою підбору параметрів зв'язку, розмірів та числа мікрорезонаторів, використовуючи періодичність резонансних частот коливань шепочучої галереї, можна реалізовувати різні смуги пропускання заданої ширини. Побудовано електродинамічні моделі режекторних фільтрів на мікрорезонаторах з коливаннями шепочучої галереї. Запропоновані фільтри можуть застосовуватись у пристроях DWDM оптоволоконних систем зв'язку.

Whispering gallery microresonators have uniquely high Q-factors, which has led to their wide application as elements of various frequency-selective devices in infrared and optical communication systems [1–3]. Thanks to active research carried out in recent decades, the design of filters based on microresonators has reached a high level of development [4]. However, along with the indicated advantage, this type of resonators also has a well-known limitation - a quasi-periodic spectrum of frequencies of natural oscillations. To compare the spectral parameters of the resonators, the concept of the frequency distance between neighboring resonant peaks was introduced: FSR - free spectral range. The frequency distance between adjacent resonant peaks for ring microresonators is inversely proportional to their radius.

The presence of a periodic sequence of natural frequencies in microresonators with whispering gallery oscillations makes it possible to use their structure, built as a bandstop filter, to obtain the frequency characteristics of scattering as for bandpass filters. In this report, we consider the possibility of implementing bandpass filters on the structure of bandstop filter by optimizing the number of microresonators and directional changes in their FSR.

To carry out numerical studies, we have developed an electrodynamic model of a bandstop filter based on perturbation theory [5]. To reduce the coupling between adjacent microcavities, it was assumed that the filter has the form of a linear array of ring microresonators with degenerate oscillations (Fig. 1, a).

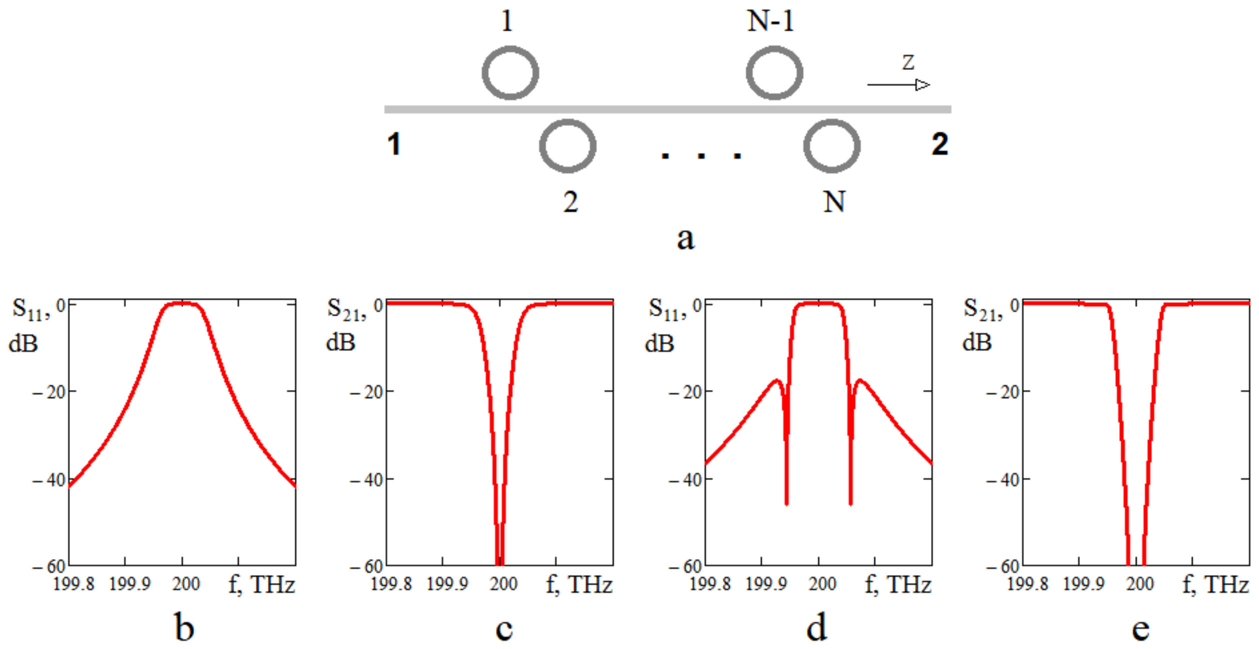

Fig. 1. Bandstop filter built on a linear array of ring microcavities (a). Scattering characteristics of bandstop filters (a) on 2 (b, c), 4 (d, e) microresonators (center frequency $f_0 = 200$ THz).

It was also assumed that neighboring microresonators are located on different sides of the transmission line at a distance $\Gamma\Delta z = (2s+1)\pi/2$ (s-integer) and are made of the same dielectric (Γ is the wave number; $\Delta z = |z_t - z_{t+1}|$; z_t is the longitudinal coordinate of the t-th resonator).

First, the scattering characteristics of structures optimized as bandstop filters were studied. (fig. 1, b - e).

At the second stage, by varying the FSR, the coupling coefficients, and the number of microresonators, we tuned and optimized the transmission parameters to the characteristic of bandpass filters (fig. 2).

As a result, we obtained the following data:

The frequency response of the first bandpass filter (fig. 2, a - d) has such parameters:

center frequency $f_0 = 199{,}880$ THz;

minimum loss in the passband -1,4 dB; -3 dB bandwidth: 560 GHz;

squareness frequency response (ratio of -30 dB bandwidth to -3 dB bandwidth) 3,7.

The frequency response of the second bandpass filter (fig. 2, e - h) is characterized by the following parameters:

center frequency 199,885 THz;

minimum loss in the passband -0,9 dB; -3 dB bandwidth: 50 GHz;

squareness of frequency response 8.

Interestingly, the narrowing of the bandwidth of the second filter did not lead to an increase in losses.

The phase-frequency dependence of both filters in the passband is close to linear (fig. 2, d, h).

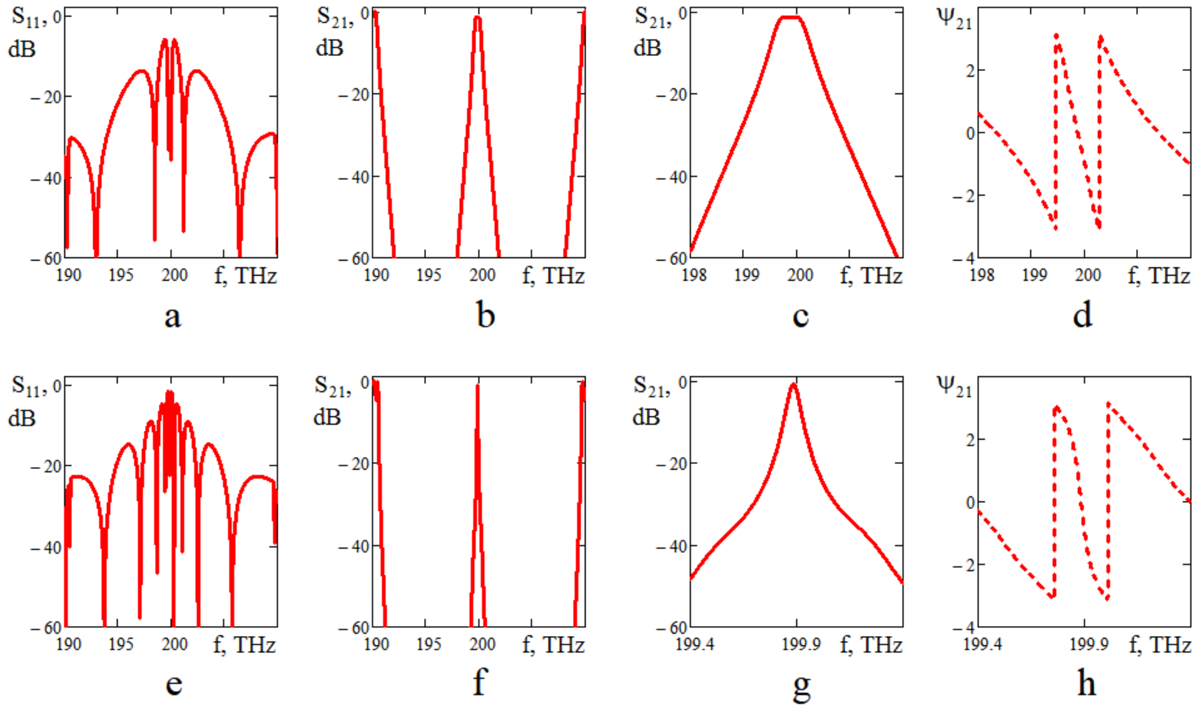

Fig. 2. Scattering characteristics of a bandpass filter based on an optimized linear array of 8 microresonators (a - d) ($N = 8$; $f_0 = 199,880$ THz; FSR: $\Delta f = 10$ THz;); of 14 microresonators (e - h) ($N = 14$; $f_0 = 199,885$ THz; FSR: $\Delta f = 9,6$ THz).

Thus, the obtained simulation results demonstrate the possibility of implementing a wide class bandpass filters based on barrier structures, using microresonators with whispering gallery oscillations. The proposed new type of filters can find practical application in multiplexers, amplifiers, lasers and other devices of infrared and optical communication systems.

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