Modelling of Bragg Gratings and Application in Cascaded Cavities

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Nowadays advanced electromagnetic numerical methods and powerful computing availability allow the analysis of most of the optical structures and devices with a great accuracy. These methods (FDTD, FEM, ...) can be extremely accurate but often they are extremely time and memory consuming, especially if 3D structures are considered. Whilst an electromagnetic approach is undoubtedly convenient for the analysis of the linear behavior, for the non-linear analysis, synthesis and optimizations of more complex devices they are often of poor utility.

In this contribution we explain how an accurate modelling of a simple building block, like the Bragg reflector, can be of great aid in both linear and nonlinear analysis of complex circuits, such as cascaded coupled cavities. The concept of using an equivalent circuit instead of a more physical description of the device is well grounded in both electronic and microwave domain and can be applied advantageously also in the optical field.

A possible equivalent circuit of the Bragg grating shown in Figure 1(a) is composed by an ideal partially reflecting mirror (r, t, φ_0) placed between two sections of propagating regions (L_e, n_0), as shown in Figure 1(b). The reflectivity r and the equivalent length L_e can be determined analytically, numerically or experimentally [1].

In the nonlinear domain the equivalent circuit can powerfully maintain its validity, provided that the nonlinear coefficient of the two sections L_e is given by $n_{2e} = n_2 L_p / 2L_e$ where n_2 is the nonlinear refractive index of the material and L_p is the effective nonlinear length, defined as the distance over which the nonlinearity really acts. By integrating the electric field over the physical length of the grating, it is found that the nonlinear length is equal to the penetration depth $L_p = tanh(kL)/kL$, that is the group length (k being the grating coupling coefficient). To show the potentialities of such an approach, let's consider two cascaded cavities defined by three gratings (detailed data of the structure can be found in [2]). The spectral behavior in the linear regime of the whole structure is the bell-shaped response centered at 1.55 μm shown in Figure 2. As the input power increases, the spectral response shifts toward the right and deforms under the effect of the Kerr nonlinearity. For high power levels, a bistability region appears on the right side of the response, close to the band-edge. The nonlinear response, both in frequency and time domain, can be computed very efficiently and a comparison with results obtained with electromagnetic simulators show a very good agreement.

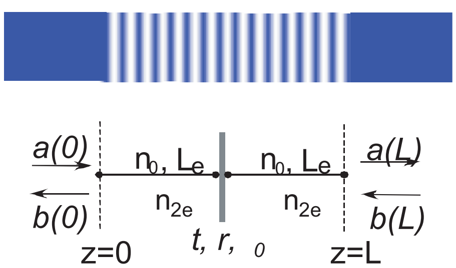

Figure 1: a) Generic bragg grating; b) its linear and nonlinear equivalent circuit.

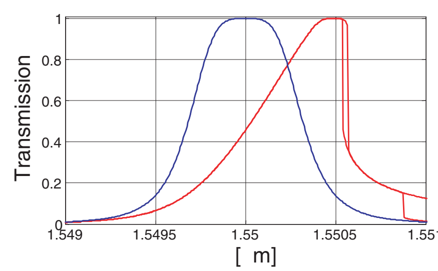

Figure 2: Spectral transfer function of two cascaded cavities in linear and nonlinear regime.

REFERENCES

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2. *Slow-wave Task of the European COST Action P11–WG2*, http://w3.uniroma1.it/energetica/