Finite-Size Resonant Sub-Wavelength Grating High Reflectivity Mirror

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***Abstract* — This paper presents simulation results on finite-sized sub-wavelength grating (SWG) optical structures. The structure is modeled with finite different time domain (FDTD). A Fabry-Perot structure built with this reflector is considered.**

I. Introduction

Sub-wavelength grating reflectors are simple, versatile, high efficiency structures and their use in integrated or free-space optical technology is very promising. Having high fabrication tolerance, a broad bandwidth and a high reflectivity make the sub-wavelength grating an excellent candidate for replacing distributed Bragg reflectors (DBR) [1] in vertical cavity surface emitting lasers (VCSELs), optical filters, and resonant cavity detectors.

There have been several groups that have fabricated sub-wavelength grating devices [2-4]. One important question that needs to be addressed is how large the grating devices need to be in order to obtain the high reflectivity necessary to construct a high-Q Fabry-Perot cavity. For ease of fabrication a small cavity size is preferred, and is the motivation for this work. Previous simulations have been performed with infinite grating size assumptions [5-6]. These were modeled using either rigorous coupled wave analysis (RCWA) or using periodic boundary conditions in FDTD simulations. Although these simulations predict a reflectivity approaching 100%, this reflectivity is expected to reduce as the size of grating is reduced.

In this paper, we show reflectivity results for finite-size grating and determine the minimum grating size for a given reflectivity. These conclusions are important for Fabry-Perot laser cavity design.

II. Simulation Results

In this section, the results from simulations are presented. The grating structure to be studied is shown in Fig. 1 (a). It consists of suspended sub-wavelength grating with the period Λ fill factor α, and an air gap thickness t. The grating is separated from substrate by G. The goal is to simulate finite grating with the size of $L_x x L_y$ as shown in Fig 1(b).

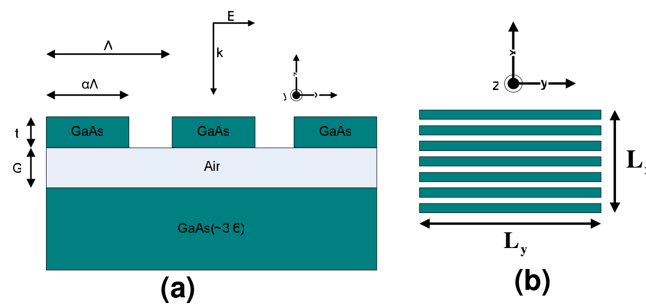

Fig. 1. SWG Structure a) Cross sectional view b) top view.

First, the infinite grating is considered. In this case the grating is assumed to be infinite in both x and y directions. Periodic boundary conditions have been used in FDTD simulation and plane wave is incident, Fig. 2 shows the reflection curve for normal incidence for the 2D and 3D simulations, where the 3D simulation predicts 99.9% reflection at 850nm. Also Fig 2. shows the reflectivity obtained from RCWA. The results are in agreement with each other.

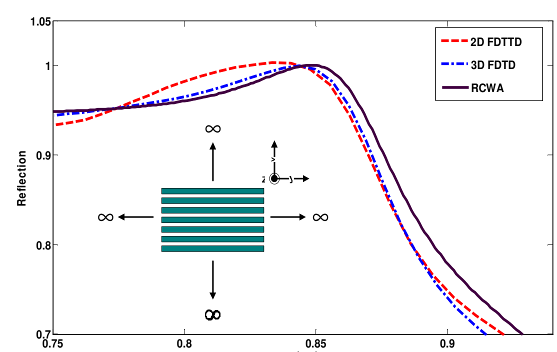

Fig. 2. Reflection of SWG using FDTD and RCWA.

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To simulate the finite structure we first consider two semi-finite cases: a) a finite number of infinitely long fingers (finite grating width of L_x) and b) an infinite number of fingers of length of L_y. These cases are investigated by adding fingers and increasing the length of the fingers gradually, respectively. Because of periodicity in these structures plane wave was used as a source. Fig. 3 shows the reflection of the sub-wavelength grating as the number of fingers is increased. From this curve, 50 periods (L_x=20μm) result in reflection more than 99.9%. Fig. 4 shows the reflection profile as the length of the fingers is increased, showing that fingers should be at least 20μm long for 99.9% reflection.

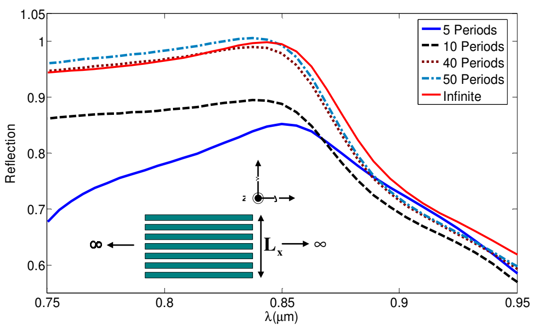

Fig. 3. Reflection of the SWG with different number of fingers

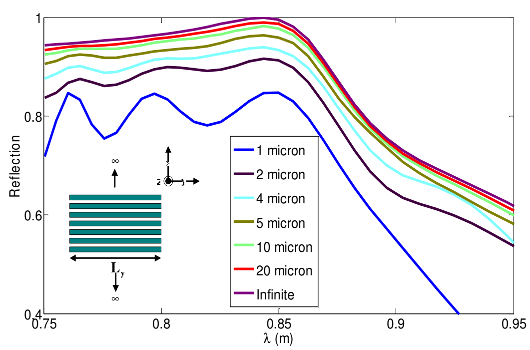

Fig. 4. Reflection of the SWG with different length of fingers

From the previous figures we may conclude that in order to get a reflection of more than 99%, the grating size should be at least 20μmx20μm.

For exact solution of sub-wavelength grating, finite case in both direction should be considered. For this case a finite sized beam (Gaussian) should be used. Fig 5. shows the reflection profile for three finite grating with 5μmx5μm, 10μmx10μm, 15μmx15μm and 20μmx20μm sizes. The Gaussian beam size was optimized for each size of the structure. It was found that a beam waist of > $L_{x,y}$/10 results in a high reflectivity.

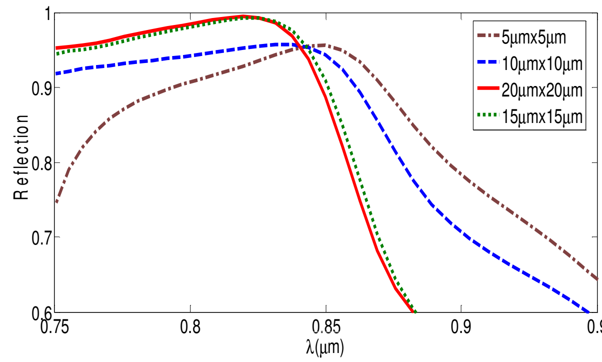

Fig. 5. reflection form three different size finite sub-wavelength

III. Conclusions

We have presented the simulation results for a high reflectance SWG which can be used as the top mirror of a lithographically adjustable Fabry-Perot cavity. The FDTD results shows that in order to have more than 99% reflection from the mirror the grating size should be 20μmx20μm in size

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