# Low Cost All Optical Swept Source for Optical Communication Applications

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By the simulation of swept light source using chirped bragg grating we can easily sweep wavelength without using any mechanical and bulky parts. At present in the market various wavelength swept light source and lasers are available, which are having various bulky mechanical parts and costly. Adjustment and purchasing of these are not easy, so with the implementation of swept light source using chirped Bragg grating does not consist mechanical parts and cost effective also.

Keywords:

## I. INTRODUCTION

In modern technology importance of optic is increased rapidly.Development of photonics is to reduce the dimension of device and to increase package density. This paper addresses problem of using heavy and bulky mechanical parts in wavelength sweeping. Adjustment of such type of arrangement is not easy and accurate. For wavelength sweep generation if we replaced these heavy and bulky mechanical parts by optical components we can get a better accuracy than present arrangement and easy alignment. These techniques become cost effective and easy to carry.

Currently report on a simultaneous dual-band wavelength-swept laser based on the active mode locking method is present. In which two free spectral ranges are independently controlled with a dual path length in configuration of a laser cavity. The static and dynamic performances of a dual-band wavelength-swept active mode locking fiber laser are characterized in both the time and wavelength regions. Two lasing wavelengths were swept simultaneously from 1263.0 to 1333.3 nm for the 1310 nm band and from 1493 to 1563.3 nm for the 1550 nm band. The application of a dual-band wavelength-swept fiber laser was also demonstrated with a dual-band optical coherence tomography imaging system[1].

We use a chirped Bragg grating for sweeping of wavelength, which simulated for sweeping 1000nm to 1550nm band. Thus we can generate a wavelength swept light source using only a chirped Bragg grating.

## II. THEORY

Fiber Bragg grating is mainly based on thin film interference filters. A cost effective scheme for carrying more information is implemented by inserting them on both sides of a fiber link. Array waveguide grating (AWGs) and etched diffraction grating (EDGs) are two typical multiplexer/demultiplexer based on planer integrated optical waveguide.

By introducing a periodic modulation in a waveguide, it is possible to create an interaction between forward-traveling and backward-traveling modes of an optical waveguide. Bragg grating diffracts light from the forward-traveling mode into the backward traveling mode. The condition for diffraction into the reverse traveling modes is called the Bragg condition. In order for light to be efficiently diffracted in the opposite direction. The reflection from subsequent periods of grating must interfere constructively[2].

The Bragg period $\Lambda$ must be related to free space wavelength $\lambda_0$ by

$$\Lambda = \lambda_0/2n_{eff} \tag{1}$$

This is condition for a first order Bragg grating. It is possible to utilize higher order diffraction to couple the forward and backward modes. The condition for constructive interference is that the phase accumulation between subsequent reflection must be an integral number of wavelengths. The Bragg gratind condition for an mth order Bragg grating is

$$\Lambda = m\lambda_0/2n_{eff} \tag{2}$$

Bragg grating is work as a optical filter. In most simple configuration a Bragg grating is an optical wavelength filter created by the periodic modulation of effective index or the physical dimension of the waveguide core. At each change of refractive index a reflection of the propagating light occurs. The repeated modulation of the refractive index results in multiple reflections of the forward traveling light. The period of index modulation relative to the wavelength of light determine the relative phase of all the reflected signals. At a particular wavelength known as the Bragg wavelength, all reflected signals are in phase and add constructively and a back reflected signal centered about the Bragg wavelength is observed. Reflected contribution from light at other wavelength does not add constructively and are cancel out and as result these wavelengths are transmitted through the grating[3].

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Bragg grating is a perfectly periodic structure which has a sharply defined begining and end point. Either by design or because of fabrication technique used, the Bragg grating will deviate some what from its perfect periodic structure. If the pitch of the Bragg grating changes slowly along the length of the grating, we say that there is a chirp. Some time, when the grating is perfectly periodic, but waveguide it self has some slow variation in its propagation constant across the length of the device, the structure will exhibit chirp like properties[4].

One application of chirped Bragg grating is to compensate for signal dispersion (pulse spreading) which occurs during transmission over a long distance of fiber.

**Optical Swept Source** -Optical sources with optical components are capable of producing light at different wavelength over a fixed range or bandwidth. For example- Bragg grating are highly reflective to light having wavelength with in a narrow bandwidth centered at a wavelength generally referred to as the Bragg wavelength. Light which having wavelength out of this narrow bandwidth range is passed without reflection. Bragg wavelength can be determined by obtain data from a Bragg grating with a light source swept across a bandwidth that includes the Bragg wavelength and monitoring the reflected optical spectrum at a receiver unit[5].

Wavelength sweep generation is providing light where a wavelength of the light is changed according to a sweep function: interrogating one or more reflective optical elements with the wavelength swept light to produce reflected optical signals, filtering the reflected optical signals where in a bandpass wavelength range is changed based on the sweep function to follow the change in the light's wavelength and receiving the filtered reflected optical signals for processing.

Active control varying sweep rates across different ranges. For example a sweep rate may be reduced in ranges containing spectral features of interest, allowing more measurement, which increased resolution. on the other hand, sweep rate may also be increased in order to skip or otherwise move rapidly through, other ranges. Further, particular ranges (sweep bands) may be adjusted. For example to follow the features of interest as they shift (eg. change in wavelength) over time.

## III. COMSOL EQUATIONS

Frequency domain solving equation for t he electromagnetic wave,

$$\bigtriangledown \times \mu_r^{-1}(\bigtriangledown \times E) - k_0^2(\epsilon_r - \frac{j\sigma}{\omega\epsilon_0})E = 0 \tag{3}$$

Frequency domain analysis is firstly us the wave equation for solving

$$\bigtriangledown \times (\bigtriangledown \times E) - k_0^2(\epsilon_r - \frac{j\sigma}{\omega\epsilon_0}) \tag{4}$$

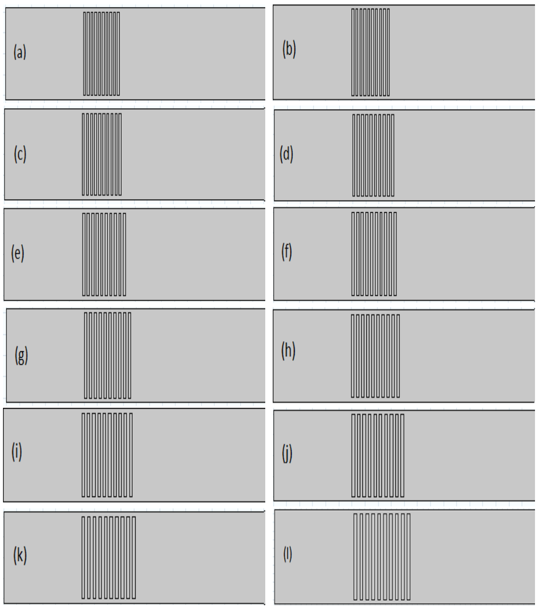

FIG. 1: (a)Design for reflection of 1$\mu$m (b)Design for reflection of 1.05$\mu$m (c)Design for reflection of 1.1$\mu$m (d)Design for reflection of 1.15$\mu$m (e) Design for reflection of 1.2$\mu$m (f) Design for reflection of 1.25$\mu$m, (g) Design for reflection of 1.3$\mu$m, (h) Design for reflection of 1.35$\mu$m (i) Design for reflection of 1.4$\mu$m, (j) Design for reflection of 1.45$\mu$m, (k) Design for reflection of 1.5$\mu$m, (l) Design for reflection of 1.55$\mu$m

Then for frequency domain use perfect electric boundary is use

$$n \times E = 0 \tag{5}$$

In the geometry port are uses to launching of electrics field according to

$$S = \frac{\int (E - E_1) \cdot E_1}{\int E_1 \cdot E_1} \tag{6}$$

## IV. RESULTS

Simulation of Bragg grating for the reflection of various wavelength is shown in Figure 1. The Figures (a)-(l) are designed for the wavelengths as mentioned above.

Reflection of 1$\mu$m grating have periodic spacing of 0.144$\mu$m, for 1.05$\mu$m periodic spacing is 0.151$\mu$m, for 1.1$\mu$m periodic spacing is 0.158$\mu$m, for 1.15$\mu$m periodic spacing is 0.165$\mu$m, for 1.2$\mu$m periodic spacing is 0.172$\mu$m, for 1.25$\mu$m periodic spacing is 0.179$\mu$m, for 1.3$\mu$m periodic spacing is 0.186$\mu$m, for 1.35$\mu$m periodic spacing is 0.194$\mu$m, for 1.4$\mu$m periodic spacing is 0.201$\mu$m, for 1.45$\mu$m periodic spacing is 0.208$\mu$m, for 1.5$\mu$m periodic spacing is 0.216$\mu$m, for 1.55$\mu$m periodic spacing is 0.223$\mu$m. Reflection of wavelength by the above design is shown in the Figure 2.

From the figure 2, we observe that the theoretical and simulated results does not go hand-in-hand. There is a

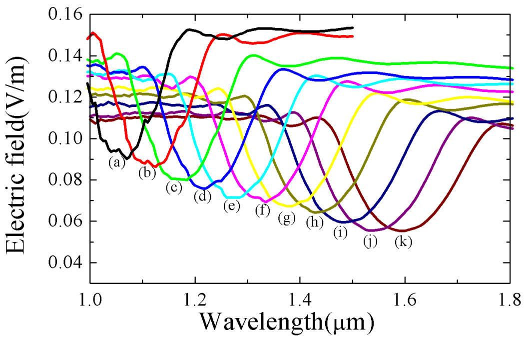

FIG. 2: Amplitude of the reflected signal is shown for designed wavelength of (a) for $1\mu$m (b) for $1.05\mu$m (c) for $1.1\mu$m (d) for $1.15\mu$m (e) for $1.2\mu$m (f) for $1.25\mu$m (g) for $1.3\mu$m (h) for $1.35\mu$m (i) for $1.4\mu$m (j) for $1.45\mu$m (k) for $1.5\mu$m and (l) for $1.55\mu$m.

definite difference in the estimated values and theoretical values. This deviation in designed wavelength and observed wavelengths are exhibited in Figure **??**. Reason for this deviation may be attributed to the approximations made under effective index calculations. We calculated effective refractive index ($n_{eff}$) by the approximation method. These deviation is shown in the Figure **??**. From the slope of the curve we found an empirical relation between the desired and designed wavelengths as

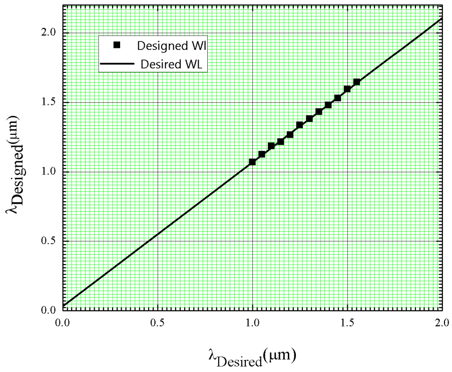

FIG. 3: Graph between Desired wavelength and Designed wavelength. The linear variation is obtained for various wavelength from $1\mu$m to $1.55\mu$m and we can obtained slope fom this graph.

$$\lambda_{designed} = 1.0374 \times \Lambda_{desired}. \tag{7}$$

The above equation is used in the calculations used in the following designed for the simulations. Such that the design made at $\lambda_{desired}$ work at the $\lambda_{designed}$.

**Designing of Chirped Bragg grating-** Since the Bragg grating reflects at the wavelength for which it is designed, we would like to find the number grating element required the reflection of the signal. To simulate Chirped Bragg grating, we optimizes that how many minimum number of grating elements are used for reflection of particular wavelength.

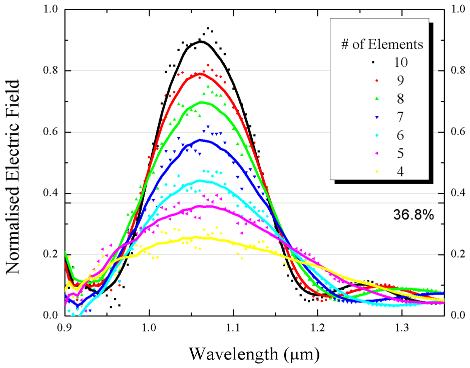

FIG. 4: Normalised reflected electric field component with wavelength. The curves are obtained for various Bragg elemenst from 4 to 10. The $1/e$ value of 36.8% is obtained for 6 or more elements.

The normaised component electric field reflected from the Bragg elements are shown in figure 4. The results obtained for different numbers of grating elements are exhibited in the figure. From the graph as we decrease number of grating element reflected electric field reduces. The $1/e$ value of reflection electric field is obtained for number of grating elements 6 or more. Accordingly, we simulate Chirped Bragg grating using at least 6 grating elements in each case for reflection of each wavelength from $1\mu$m to $1.55\mu$m. Simulated design of Chirped Bragg grating is shown in Figure 5.

Figure 6 shows simulation results for reflection of different wavelength by the chirped Bragg grating. The reflected components execute oscillations due to the interference between the forward and reverse propagating em waves. In each design we used in Chirped Bragg grating first six grating elements each for every wavelength from $1\mu$m, to $1.55\mu$m with step size of 5nm. The chirping arising due to this can also be understand from the Graph 7. In Graph 7 we can see that $1\mu$m wavelength have negligible intensity after some sort of distance. As wavelength is increased distance also increased to decrease intensity.

## V. CONCLUSIONS

In conclusion, Bragg grating using using Silicon waveguide and using multiphysics simulation tools are ducces-

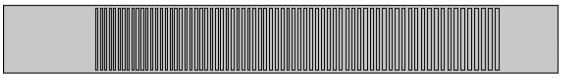

FIG. 5: Simulation of Chirped waveguide Bragg grating

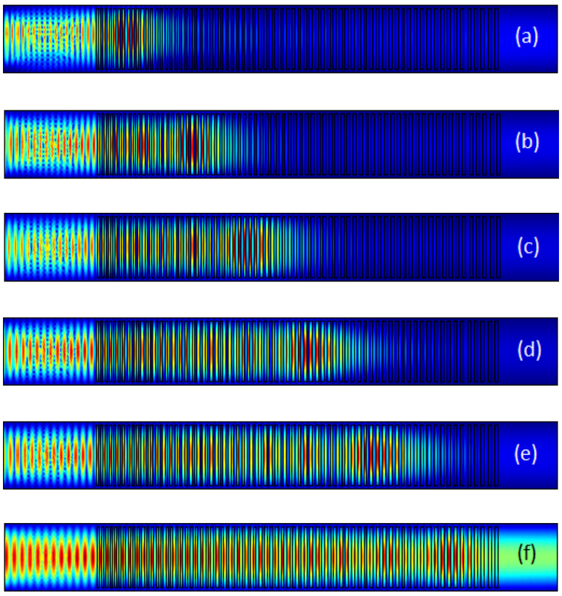

FIG. 6: Simulation results of Chirped Bragg grating. (a) for 1$\mu$m (b) for 1.1$\mu$m (c) for 1.2$\mu$m (d) for 1.3$\mu$ (e) for 1.4$\mu$ (f) for 1.6$\mu$m. From 1$\mu$m to 1.55$\mu$m wavelength is reflected by simulated chirped Bragg grating and others get transmitted.

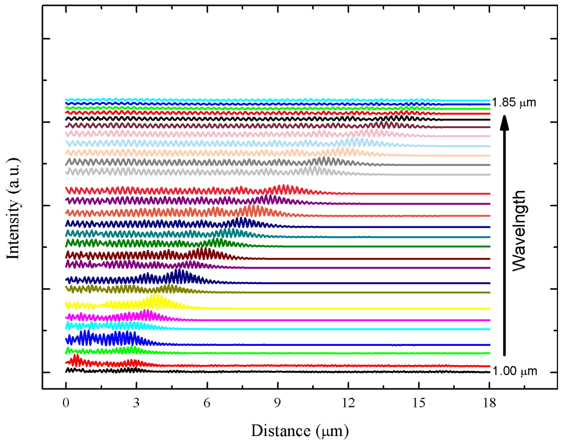

FIG. 7: Intensity Vs Distance. Propagation of wavelength from 1$\mu$m to 1.8$\mu$m in chirped Bragg grating is shown by this graph.

fully demonstrated. It is shown that the Bragg grating reflect the desired wavelength. The Chirped Bragg grating are found to delay different wavelengths in time and may act as swept wavelength source. The proposed device is very compact and could be useful in various applications including OCT and Optical Communication. The broadband spectra needed to be understood in time domain and space domain simultaneously.

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