New widely tunable laser concepts for future telecommunication networks

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Abstract **Future telecommunication networks will rely on widely tunable lasers to provide extra flexibility, functionality and performance. At the moment, these lasers still have disadvantages compared to non-tunable lasers. Our research aims to develop a couple of new designs which eliminate these disadvantages.**

Keywords **tuning, optical communication, semiconductor laser**

I. INTRODUCTION

Telecom operators worldwide are facing a rapidly increasing bandwidth demand due to the exponential growth of the internet and the advent of broadband technologies. Optical fiber has therefore become the preferable medium for telecommunication.Wavelength Division Multiplexing (WDM), with different channels being encoded on different wavelengths and being sent through the same fiber, is introduced to increase the bandwidth even further. At the same time there is a trend toward more flexible and all-optical networks, e.g. reconfigurable networks with easy channel provision. It is expected that wavelength tunable lasers will play an important role in this network evolution. With tunable lasers that have the same quality as non-tunable lasers, operators will be able to reconfigure their network very fast and cheap: they add extra flexibility, functionality and performance to the network.

The many advantages have led to a multitude of tunable laser concepts in the past years, but not one of these concepts has the same qualities as (non-tunable) DFB lasers (high output power and high side mode suppression) and is widely tunable, easy controllable and easy manufacturable. This PhD aims to develop and investigate new widely tunable laser concepts that have all those qualities.

II. LASER BASICS & TUNING

A. DFB Lasers

A distributed feedback (DFB) laser (Fig. 1), consists of a an active layer responsible for optical amplification and a wavelength selective reflector or filter. Amplification and filtering in a DFB laser are combined in one section, but in other concepts those functions are often carried out in different sections.

A uniform diffraction grating is frequently used to obtain the aforementioned wavelength selective behavior: the refractive index of the laser structure is periodically modulated and the light is reflected at every refractive index change. Those reflections only interfere constructively in a small frequency range and lasing occurs at only one wavelength (Bragg wavelength):

$$\lambda_B = 2\ \Lambda\ n_{eff} \tag{1}$$

From this formula, it's clear that tuning can be obtained by changing the refractive index $n_{eff.}$ This can be done by injecting current into the grating or by heating the grating, but the tuning range is limited to a couple of nanometers due to the physical limitations of both methods.

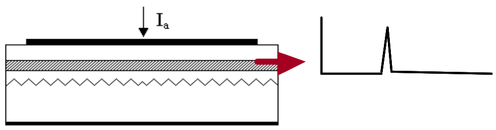

Fig. 1. DFB laser with a uniform grating

B. Sampled and Superstructure Gratings

By sampling a uniform grating (Fig. 2(a)) , one obtains a spectrum with several reflection peaks centered around the Bragg wavelength with the peak spacing being inversely proportional to the sampling period. The reflection spectrum of a sampled grating (SG) is not uniform and the reflection is decreasing with the deviation from the Bragg wavelength. Sampled gratings can be easily manufactured through holography.

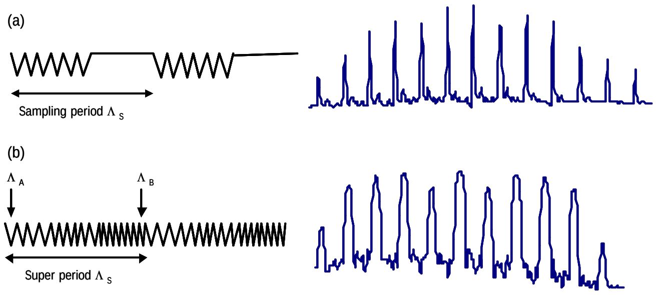

Fig. 2. Two superperiods and a typical spectrum for a sampled grating (a) and a superstructure grating (b).

Superstructure gratings (SSG) are another way of sampling a uniform grating to obtain multiple reflection peaks (Fig. 2(b)). Within the superperiod Λ_S the grating period is varied continuously or in discrete steps between Λ_A and Λ_B causing

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reflection peaks between λ_A ($= 2\, n_{eff}\, \Lambda_A$) and λ_B ($= 2\, n_{eff}\, \Lambda_B$). The peak spacing is also inversely dependent on the superperiod, but the envelope of the reflection peaks is significantly more uniform than with sampled gratings. The drawback of this method is its fabrication. E-beam lithography, a very costly and time-consuming method, has to be used in order to obtain superstructure gratings.

C. *Wide Tuning*

Widely tunable lasers contain two different reflectors: two sampled or superstructure gratings with slightly different superperiod are used causing a slightly different peak spacing in the reflection spectrum. Lasing occurs when peaks of both sections overlap, so by slightly changing the refractive index of one grating section two other peaks that are further away will overlap (Vernier effect) and tuning over a wide wavelength range is obtained (Fig. 3).

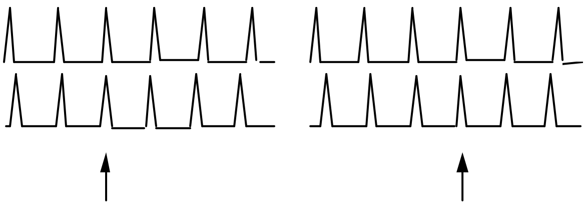

Fig. 3. Lasing occurs where 2 peaks align. A large wavelength jump occurs by a small spectrum change in one section

An SSG-DBR (fig. 4) is an example of a widely tunable laser that uses the Vernier effect to obtain a tuning range of more than 30 nm [1]. It consists of 2 reflectors with slightly different sampling period. This results in a very selective filter. There's also an active section, which is responsible for light amplification and a phase section that guarantees the alignment between the cavity mode and the reflected peaks.

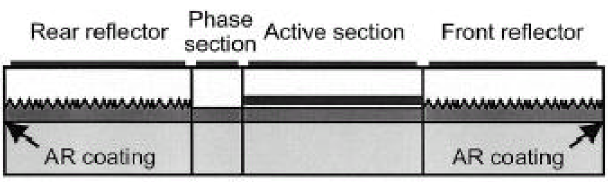

Fig. 4. An SSG DBR Laser

Stable lasing is guaranteed by the very selective filter. Unfortunately it doesn't have a large output power due to the use of reflectors at both sides. A time consuming characterisation is needed due to the use of 3 independent tuning currents.

III. INTRODUCING TWO NEW CONCEPTS

A. *Widely Tunable Twin Guide(TTG) Laser*

A widely tunable twin-guide (TTG) laser [2] is a two section TTG laser (Fig. 5), in which both sections contain a sampled grating or a superstructure grating with different superperiod. Current injection into the tuning layer is used to change the effective refractive index and the Vernier effect creates tuning over a wide wavelength range (several tens of nm).

Only two tuning currents are required to obtain full wavelength coverage over a wide tuning range, which makes the characterisation substantially less time consuming. We also expect a high output power and a short device length, but the production yield could be lower due to its complex fabrication. These lasers are manufactured in cooperation with the Technical University of Munich.

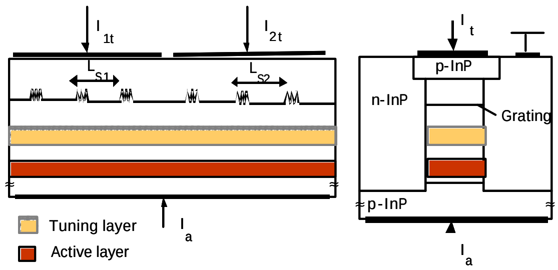

Fig. 5. A Sampled Grating Tunable Twin-Guide (SG-TTG) Laser

B. *Widely Tunable Y-Branch Laser*

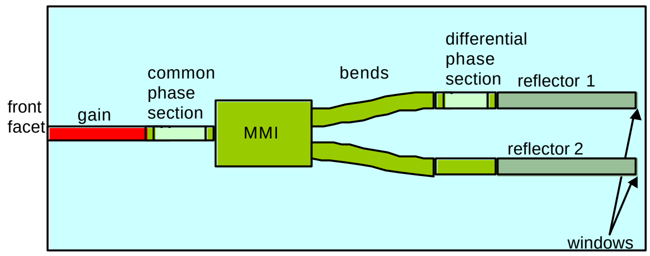

Fig. 6. A widely Tunable Y-Branch Laser

In the widely tunable Y-Branch laser concept [3], the different functions are separated into different section (Fig. 6). The gain section amplifies the light. The MMI splits the light into 2 equal beams. The reflectors filter out certain frequencies. The differential phase section guarantees that the reflected beams are added up in phase. And the common phase section is responsible for the alignment between the cavity mode and the reflected peaks.

The need for 4 independent tuning currents in this device is a potential disadvantage, because the characterisation becomes time consuming. On the other hand, a high output power is expected and it has a simpler fabrication compared to the (S)SG-TTG.

ACKNOWLEDGEMENTS

Part of this work is carried out for the IST project NEWTON.

Reinhard Laroy acknowledges the Flemish Institute for the Industrial Advancement of Scientific and Technological Research (IWT) for a specialisation grant.

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