13D1-1 (Invited)

Tunable Lasers for Optical Systems; Technologies and Commercialisation

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Abstract

We will give an overview of different tunable laser technologies and compare the different aspects of their performance. This will be related to the current state of commercialisation. Some present lines of development will be discussed.

Why tunable lasers?

The main argument for the use of tunable lasers is the reduced cost (and logistic complexity) of sparing. If tunable lasers become sufficiently cheap, they might even replace fixed wavelength lasers, at least for use in high data rate DWDM systems. In addition tunable lasers offer flexible provisioning and also support new network features based on the use of wavelength routing. One can use wavelength switching either as circuit switching or as packet switching.
Due to the attractions of tunability there has been intense activity on research and development in the last 20 years, and tunable lasers was one of the hottest areas in optical components during the telecom bubble. The arguments for tunability are still valid, and we now see the emergence of a significant market, and a second wave of interest is building up.
Tunable lasers are also of interest for test and measurement applications as well as for various sensors, but in this presentation we will focus on lasers designed specifically for optical transmission.

Technologies and standards

We restrict the discussion below to lasers capable of covering a full band (at least 30nm), this means that thermally tuned DFB lasers and standard DBR lasers will not be included.

Widely tunable lasers can broadly be subdivided into 4 groups of structures which each have specific advantages and drawbacks:
DBR lasers with extended tuning range.
These have two special design gratings, with either one at the front and one at the back, or with both in parallel at the back. The main advantages are tuning speed, integrability (with SOAs and/or modulators), and component size. However, wavelength control is a challenge.
DFB (or DBR) arrays.
A combiner function is required. If this is implemented monolithically the output power has to be boosted with an SOA and the chip becomes large. Use of an external combiner allows a high output power, but involves a moving part (MEMS mirror).
In DFBs the wavelength tuning of each array element is thermal, and therefore simple but slow.
DBR arrays offer fast (partially continuous) tuning, but again a combiner is required.
Tunable VCSELS.
These are small and relatively simple, but the power level is low. There is little current commercial activity.
External cavity lasers (ECLs).
A variety of versions exist, and generally they offer a high optical power, a wide tuning range, and a narrow linewidth. The main issues are: size, drive requirements for the tunable filter or mirror, and tuning speed (at least in the case of thermal tuning).
More details on the different technologies can be found in [1].
In order to promote the introduction of tunable lasers, groups of manufacturers have entered into multi source agreements (MSAs). One example is the Integrable Tunable Laser Assembly (ITLA). This agreement specifies the physical size (74mm x 30.5mm x 10.5mm), the optical performance, and the control interface of a CW tunable source. ITLAs from

different manufacturers are completely interchangeable, and the actual laser structure and tuning mechanism is "invisible" to the user.

Companies (past and present) and market

Due to the large interest in tunable lasers during the "bubble" years, a number of companies were started with tunable lasers as the main or only product. With two exceptions these companies no longer exist: Agility (SG-DBR) now taken over by JDSU; Santur (DFB array) is still privately held.
Some companies have tunable lasers as a part of a wider portfolio of products, examples are: Intel (ECL), Bookham (DS-DBR) and Pirelli (ECL). A number of companies had tunable laser activities (mainly on DBRs) in the past, but seem to have stopped, these include: Agere (Lucent), Avanex (Alcatel), Multiplex and Agilent.
With the renewed interest after the burst, a couple of new specialist tunable laser companies have emerged during the last few years: Paxera (ECL) now taken over by Neophotonics and Syntune (MGY-DBR).
It is noticeable that developments in Japan have been much less turbulent with no start-ups, no take-overs and no company closures. It is also noticeable that the Japanese activities are biased towards DFB arrays (Fujitsu, Furukawa, NTT) and ECLs (Fujitsu, NEC). In addition there is work on DBR arrays, ring resonator structures and the TDA-DFB.
In a study published in 1999, a market of 30M$ was forecast for 2002, growing to almost 1G$ by 2005. In reality the development has been lagging this prediction by at least 3 years, but we are now finally seeing a strong commercial interest with 10s of thousands of units being shipped per year and a significant growth rate. Currently the largest suppliers are Santur, JDSU (Agility), and Intel.

Pluggable tunable?

With the emergence of small form factor pluggable transceiver modules, such as the XFP, the sparing argument for tunable lasers has been somewhat eroded since the cost of sparing has been significantly reduced. The challenge is therefore to develop a tunable *and* pluggable transceiver module for 10Gbit/s with full band coverage. This requires a small laser package (e.g. TOSA), and a low power consumption since the thermal management is a major issue. A step towards this goal is the recent development of a laser monolithically integrated with a MZ modulator.

DWDM vs CWDM

Current lasers for DWDM requires the use of a thermo electric cooler (TEC) in order to avoid thermal drift of the wavelength. CWDM on the other hand does not require cooling, but the resulting 20nm channel separation reduces the spectral efficiency significantly. An interesting approach is to use tuning to compensate for thermal drift. This would allow a channel spacing of a few nm without the added cost of the TEC. A couple recent developments in this area will be described in more detail.

Conclusion

The attractions of tunability have not disappeared with the burst of the bubble, but the commercialisation has been slowed down by a number of years, and most of the start-up companies from the late 90's have not survived. The market now finally seems to have taken off with a significant number of units being sold and with a good growth rate.
New companies are emerging, new technologies are being explored, and there is significant interest in miniaturisation, improved performance, increased functionality and cost reduction.

References

[1] J. Buus, M.-C. Amann, and D.J. Blumenthal, "Tunable laser diodes and related optical sources, Second edition", Wiley, Hoboken, New Jersey, 2005.