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TECHNOLOGY FOR TUNABLE LASERS

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Abstract*:* Many key technology lists for next optical communication and sensing systems include tunable semiconductor lasers. This essay offers a tutorial's summary.This was presented at OFC '03. It touches on some justifications.Tunable lasers could be useful, and a basic tuning sketcha few examples of tunable lasers that have been developed, methods,commercialized, and a look at control methods. MoreFor the widely-tunable sampled-grating, significant data is provided.laser of the distributed-Bragg-reflector (SGDBR) type, with data such lasers must be monolithic ally integrated with modulators to provide front ends for entire transmitters. Reliability information for Also provided is the SGDBR laser. The results show that tunable lasers can lower operating expenses, making full-band tunability attractive.That monolithic integration gives benefits for many applications.the greatest potential for lowering cost, size, weight, and power, and that sufficient reliability for system insertion has been proven.

keywords: Tunable lasers, semiconductor lasers, and photonic integrated circuits.

I. INTRODUCTION

A laser whose wavelength may be changed is referred to as tunable. While every laser gain medium permits slight changes in the output a limited number of laser types and wavelengths Permit continuous tweaking over a substantial wavelength range. Different tunable lasers from conventional lasers due to their constantly altering their output colour or wavelength within a specific spectral range range. a laser with variable wavelengths frequency of radiation emissions inside a specific range of UV, visible, and IR the electromagnetic spectrum's several bands.In WDM, or wavelength multiplexing 128 wavelengths of the network conveying We have 128 separate lasers that emit these wavelengths of light for information. Each laser is uniquely created to deliver the precise wavelength required. in spite of Because lasers are expensive, we should be able to swap them out right away so that We don't lose any of our available capacity.so much money was invested in. Therefore, we continue. 128 extra lasers on hand, or even more Just to prepare you for a double failure, 256. The equipment itself is still solid-state. similar to the way that a laser works the standard, unchangeable versions. Most designs incorporate grating of some kind, such as similar to those found in a distributed feedback laser. It is possible to modify these gratings to adjust the wavelengths in the laser cavity that they reflect, often by passing a stream of electricity through them, altering their refractive index. The range of adjustment for such Devices can be as small as 40 nm, which 50 distinct wavelengths in a single cover system with a 0.8 wavelength separation nm. Vertical-cavity-based technologies VCSELs are surface-emitting lasers. changes to the cavities' movable ends the cavity's length and, thus, the emitted wavelength. A tunable VCSEL for current Tuning ranges are comparable between designs.

II. METHODOLOGY

Tunable lasers are essential in a wide range of applications, including telecommunications, medical devices, and scientific research. A clearly defined method must be used to ensure that the laser meets the requirements of the intended application is applied to create tunable laser technology. The first step in creating products is identifying the needs.laser engineering. determining the required wavelength range for the use, the planned output power, and additional requirements for stability, noise, and tuning speed are all comprised in this. Using this knowledge, the ideal laser for a certain application might be selected, taking into consideration cost, complexity, and performance factors. The ensuing phase is to choose the type of laser before designing it. This requires selecting appropriate components, such as optimizing the design for the intended wavelength range and output power, using mirrors, lenses, and gain medium.

III. WHY TUNABLE LASERS

Even if we have already said that the current argument for wanting to use telecom technology is not the only one, there are still a number of prospective applications in the sector that may be relevant in the near future.The manufacturing of tunable laser solutions has been reduced.operational expenses brought on by a drop in inventory. ROADMs are adaptable optical-adddrop multiplexers.the first to be mentioned, make replacement and removal possible without de-multiplexing, regenerating, or re-multiplexing the entire fibre, of one or more optical channels.wavelength spectrum found in the fibre. Using the ROAD considerably reduce the price of removing or adding a very little information from or to the fibre in circumstances in which this capacity is desired.

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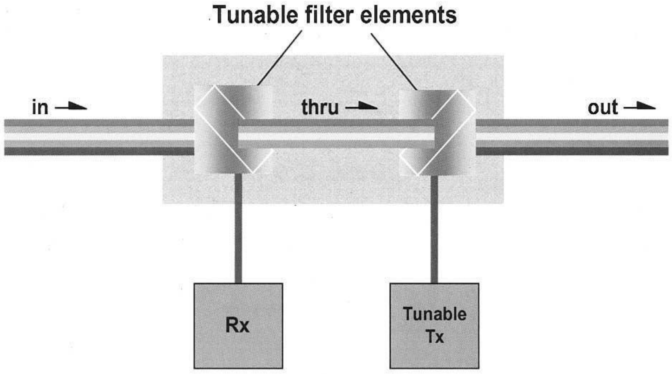

Fig 1. Tunable Filter

Additionally, tunable lasers work well with different kinds of optical switches. Here, they are often used for "wavelength conversion," also known as wavelength switching, which entails remodulating an existing signal.incoming signal on the output transitioning from one wavelength to another. Although there are various ways to accomplish this, the simplest is to a line card or transponder with a tunable laser will enable the Any wavelength value may be used to alter the output. to reestablish These "opticalelectronic-optical" devices return a signal to its original shape.Components of (OEO) include 3R regeneration. Another choice the development of "all optical" wavelength converters that power a modulator directly with an input signal at one wavelength and apply it to a second, chosen output wavelength.

IV. BASIC TUNING MACHINE

This provides a combined schematic for a generic tunable laser. the locations of the numerous cavity modes that must all be present, the relative spectra of the required filter and gain components, and be correctly translated and aligned to produce a single-frequency, tunable laser. Of fact, in the majority of usage scenarios, the Each of the various tunable laser types has a unique physical design that incorporates filter, mirror, and phaseshifting elements

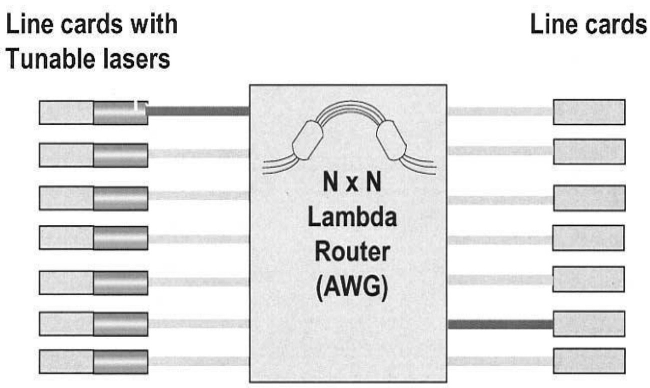

Fig 2. Tuning Machine

One may observe the evolution of a tunable semiconductor laser from the simplest "Fairy-Perot" laser, which simply has the gain and two fundamental mirror elements, to a more complex laser.mode-selection is added via a "single-frequency" laser.a "tunable single-frequency" laser that adds the filter to the ability to move the mirror's centre and position Increasing the mode-selection filter's frequency and include a new cavity phase element with adjustment. Readers are instructed for an analytical justification.

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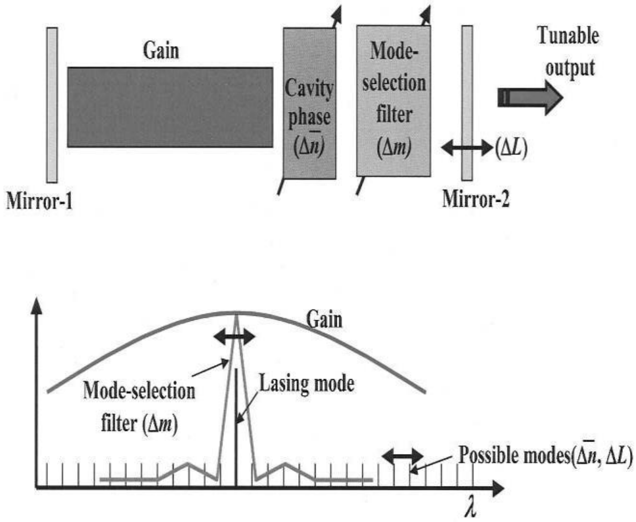

Fig 3. Generic Tuning Machine

V. EXAMPLES OF TUNABLE LASERS

Displays a variety of different commercially available, tunable single-frequency laser types. (As tunable lasers must only have one setting, we will now omit this requirement.)For much practical use, only the widely-tunable kinds that are capable of offering total C or L-band coverage from a In the picture, only one device is visible. A multi-mode interference coupler is shown in the first example is created utilizing a DFB laser array that is programmable. Each DFB is created with a slightly modified grating pitch to prior to being shifted by 3 or 4 nm, a device's output wavelength one by one excited.

Accessing the wavelengths is necessary.between the discrete array component values and the chip afterwards heated by 30 to 40 C. Utilizing -DFB When 8–10 elements,The full C-band may be reached or a wavelength can access a range of up to around nm. The design in Fig. 5(a) was made by NEC[11], although similar work has also been done by other labs, primarily in Japan. Santur Corporation uses similar technology, however They use an external MEMS (microelectromechanical systemst to determine which component is connected to the output fibre. This prevents combiner loss but adds one more step.element to regulate and package. Always use this technique discuss the requirement for many, widely spaced DFBs that must all execute to a high standard. the costs associated with merging are common to most types and also significant.

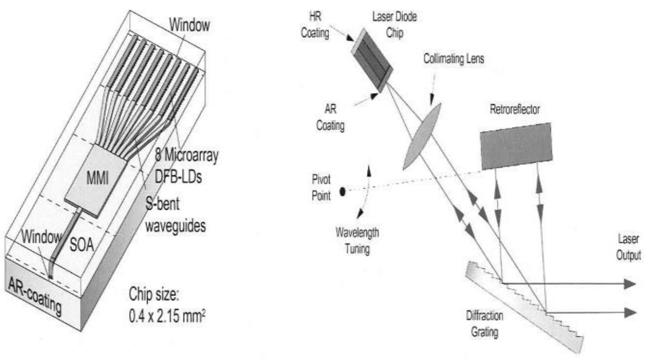

Fig 4. Tunable Lasers

factive cavity length to track the motion of a single cavity mode in proportion to the fluctuation in the centre wavelength of the mode- selection filter. Continuous tuning is provided by Littman-Metcalf geometry over some range, but generally The cavity phase at each ITU channel needs to be fixed.as a result of cavity dispersion.

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VI. CHARACTERSTICS OF SGBDR LASERS AND SINGLE CHIP TRANSMITTER

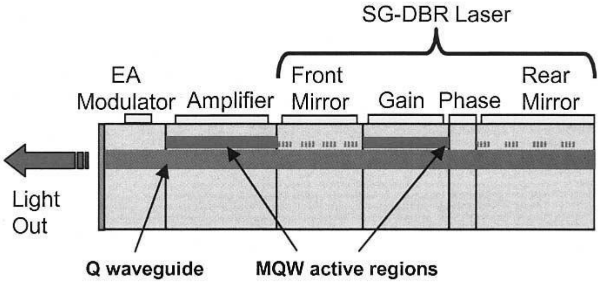

Fig 5. Single chip Transmitter

A cross section of an InP-based transmitter in schematic form. The modulator bias is chosen to enable efficient modulation and sufficient extinction over the entire 40 nm tuning range.changed. Rf-extinction ratio against wavelength displays for 100 transmitter chips in the C- band following transmission, attributes, and displays the bit-error rate over 350 miles of standard single-mode fibre for separate wavelengths. The chip's EAM is supplied with the data immediately. The typical modulated output in this case Power is around 3 dBm. An error-free operation was noted.The transmitter and described delivers for distances up to satisfactory performance at 2.5 Gb/s rates, some form of chirp control is required. Therefore, aim for Although a completely programmable chirp requires dual drive of both MZM arms, such modulators have been widely used for long-distance applications utilizing just one driving signal, and allow negative chirp. in light of considering the difficulties researchers have faced in the past utilising such MZMs in conjunction with lasers. Yet, it appears that these difficulties have been overcome by the UCSB-Agility effort. In contrast to hybrid packed or fiber-coupled gadgets, the By monotonically integrating, MZM can have a substantially smaller footprint and low power dissipation. Each channel may be altered by varying the biases to the two legs of the MZM.across the range of wavelengths. values between and for chirp are simple to get to. Using a negative chirp configuration, flawless It was demonstrated that transmission over 80 kilometres of standard fibre was achievable at 10 Gb/s for all channels.

VII. RESULTS

The statistics gathered for the 10 mW cw product from Agility [31]. Both the integrated EAM transmitter and the 10 mW cw variant have successfully completed the entire Telcordia qualification process. These PICs may be qualified similarly to how basic contractors are. Due to the InP singlechip architecture, laser chips. Alternative types widely-tunable transmitters, each of which makes use of a different optical Components contained in a hybrid package do not experience this issue. By fully outlining failure mechanisms and pinpointing failure rate modelling using failure mode accelerants was made for every part of the device. The turning on The calculation of energy used a proportionate ageing rate. assumption. It was believed that the ageing rate was proportionate.Where is the applied force in order to calculate the current acceleration exponent?

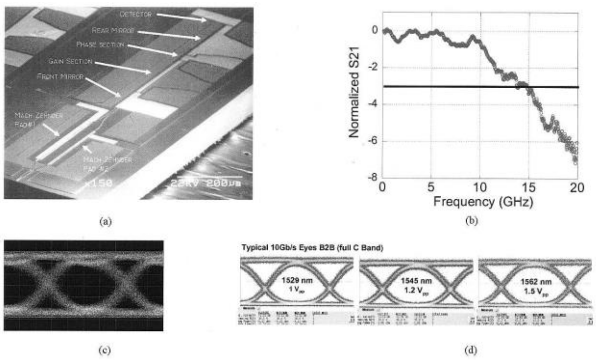

Fig 6. Diagrams for the Agility device at 10 Gb/s for three wavelengths spanning the band are shown in (a) SEM image of the UCSB SGDBR with a Mach-Zehender modulator integrated, (B) small-signal bandwidth, (C) an unfiltered eye, and (D) a filtered eye.

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FIT rate against time, bias updating-mirror with and without assuming both initial mirror biases, control. Distribution (b) during the lifespan of 200 tested components. Maximum is assumed current channels. 186 years are lived on average. years.effect that a component of a traditional system has Distribution wouldn't offer anything. a WDM distribution the "no mirror" policy for channels is taken into consideration. The predicted control" FIT rate is 2 @ 15 years.

The relatively little wavelength drift of the SGDBR has been attributed to the small quantity of grating that occupies the sampled-grating mirrors. Typically, a design includes On about 90% of the mirror area, there are no gratings. This leads to Mirrors have material quality that is noticeably higher, per studies [31]. The majority of locations lack grating permits extremely high quality InP cladding development after creation of grating. The surface is more uniform and flat than In the vast expanses between the grating bursts, it can be made of InP rather than In GaAsP qua-ternary wave-guide material if it is defect-free. As a result, the SGDBR has solved the wavelength drift issues that regular DBR lasers, which include gratings throughout the mirror tuning portions, still have.Surprisingly, it showed up stable.

VIII. WIDELY-TUNABLE LASER CONTROL

Longstanding barriers to the widespread adoption of multielement tunable lasers, such those shown in Fig. 5, include their control. system engineers are typically used to including a twoterminal device, like a In their optical transmitters, DFB laser. Naturally, even for the To fine-tune and lock the device, DFB the device temperature is employed. wavelength in systems using WDM. In regards to the widely-tunable gadgets It's clear from Fig. 5 that we must concurrently control a few other factors, though occasionally we may The same number just needs to be dynamically controlled in the DFB to lock the wavelength and amplitude at a certain channel. However, a "look-up table" is always required to provide the particular set of currents or voltages for each channel to the several sections, and this indeed, does add a complication for the user.

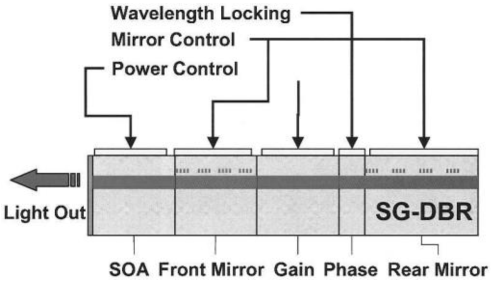

Fig 7. Tunable laser

To be accepted more widely, multiple-section supplier Laser modules now feature automatic control systems so that consumers don't have to worry about them. the problem with command. A digital command is sent through a shared interface. is used to set the amplitude and wavelength. Clients are Concerned about the dependability and stability is understandable nonetheless, of such systems. They continue to pique my curiosity.

The control system needs to be capable of two primary responsibilities: 1) ensuring exact alignment with the target wavelength channel and 2) finding a new one in the right place. when a later, possibly lifetime, channel is the channel There is a change request. most lasers require different. in order to accurately maintain a selected wavelength locker for channels. Possibly, this locker is not be required if the wavelength channel plan is sufficiently coarse.For instance, this locker may not be necessary due to the SGDBR's capabilities if a low FIT rate is acceptable at even 100 GHz channel spacing. very little wavelength drift. But a locker is more essential. frequently.

For the purpose of catching and locking the wavelength within a channel spacing of around one-third on each side of It frequently has an etalon with a free-spectral range that is about equal to the channel spacing and operates at the ITU frequency.

Eventually, switching channels is usually a more difficult problem. Will the factory's original look-up table work? Does the calibration still work? Is it sufficient? Has ageing changed the standards? The controls must direct us to the appropriate interior channel.

Use the original look-up table to find the locker's capture range. The look-up table for embodiment where tuning is used tends to alter as a result of hysteresis and charging of MEMs components.requires mechanical movement or high

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temperatures fluctuations. Alterations in carrier lifespan could also result in some DBR designs have a wavelength shift that is outside the capture range for lockers. a method for channel counting,a technique for updating the global wavelength monitor Over time, look-up tables may provide an answer to these issues. These tactics have all been tried and tested, yet none of them call for control systems that are substantially more advanced.

IX. CONCLUSION

As noted in the OFC'03 lesson on tunable solid state lasers, we talked about reliability concerns, presented control strategies, and provided some examples of commercially available tunable lasers and described fundamental debugging techniques in the majority of tunable lasers. An overview of the statistics on performance for the monolithically integrated lasers of the SGDBR and SGDBR with electro absorption, as well as It used Mach Zehnder modulators. given. a few have claimed that many situations call for fullband tunability. the number of uses for tunable lasers can be operational effectiveness. Considerations that the ability to With the least amount of size, weight, performance, and expense monopolistic integration, as well as the necessary dependability for There has been evidence of system insertion, at least in the case of SGDBR.

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