Use of fast wavelength tunable laser modules essay



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Introduction

The phenomenal growing of the Internet over the last decennary has driven the development of telecommunications traffic from voice based real-time traffic to internet protocol (IP) based package traffic. The associated growing in traffic volumes has, therefore far led to the development of circuit switched reconfigurable dense wavelength division multiplexed systems (DWDM) to better use the tremendous capacity offered by optical fibers originally deployed for individual or multiple wavelength point-to-point links. With the continued growing of broadband demand and the debut of new services such as voice-over-IP and IP telecasting, the package traffic is going progressively sensitive to the high latency feature of today ' s reconfigurable circuit switched optical webs. The demand for high throughput and decreased hold has hence resulted in great involvement in the development of optically packet switched systems.

Wavelength tunable optical masers are rapidly going a mainstream constituent in optical webs. In add-on to supplying immediate cost economy for deployed wavelength division multiplexed webs, in footings of back-up senders and stock list decrease, these devices besides have an of import function to play in future optically switched webs. The intent of this thesis is to look into the usage of fast wavelength tunable optical masers in such systems. In these systems a tunable optical maser (TL) can be used to bring forth optical packages at finish specific wavelengths, which can be routed to their appropriate web nodes by utilizing simple optical wavelength filtrating https://assignbuster.com/use-of-fast-wavelength-tunable-laser-modulesessay/ techniques. This thesis is based on experimental work carried out utilizing a TL faculty developed by Intune Technologies Ltd. for such systems.

The work was supported by Science Foundation Ireland and was carried out in the Radio and Optical Communications Laboratory, Dublin City University and in the Photonic Systems Laboratory at the Tyndall Institute, Cork

The chief parts of this work are:

Specious Mode Blanking Investigation – A semiconducting material optical amplifier can be used to rarefy the specious manners generated as a TL melodies. This blanking has been by experimentation demonstrated to greatly cut down system public presentation debasement from the tuning of multiple TLs in a WDM system.

Word picture and System Impact of TL Wavelength Drift – The initial wavelength impetus of a TL faculty, after tuning, has been characterised and two attacks (extended blanking & A ; sub-carrier multiplexed transmittal) have been demonstrated to get the better of this impetus, therefore leting for mistake free transmittal in a 12. 5 GHz spaced ultra-dense WDM system.

Optically Labelled Packet Switched System – The spot error rate as a map of clip was correlated with the wavelength impetus from a TL faculty in a spectrally efficient (0. 4 b/s/Hz) optically labelled package switched system.

The light beginning used for DWDM channels is of cardinal importance and is frequently the most dearly-won component in the web. The light emitters of pick are high declaration preciseness narrow set semiconducting material optical masers fabricated with Indium Gallium Arsenide Phosphide (InGaAsP) on Indium Phosphide substrate. In today 's webs visible radiation is launched onto any of the supported wavelengths utilizing exactly fabricated individual wavelength distributed feedback optical masers (DFBs). The DFBs operate on specific fixed wavelengths as fit Forth in the ITU recommendation G. 694. 1 [16] for DWDM webs with 100, 50, 25 and 12. 5 GHz channel separation. The optical maser parametric quantities that are of import for web operation are end product power, side manner suppression ratio (SMSR), wavelength stableness, line breadth and lifetime. A description of current and future DWDM tunable semiconducting material optical masers is given in Chapter 2.

Tunable Lasers in Optical Switched Networks

Tunable optical maser (TL) development will play a cardinal function in the success of the possible optical webs described in the old subdivisions. Presently the primary applications of TLs in optical webs are saving, dynamic provisioning and channel Restoration. Tuning velocities for which are on msec timescales [37].

The debut of OBS will increase this tuning demand to the order of microseconds. Future webs utilizing TLs to execute optical shift of single packages (i. e. OPS), will increase the demands even further. This could include the usage of TLs as tunable senders on which packages will be encoded on finish dependent wavelengths [38]; or as local optical masers in tunable wavelength convertors to route packages by puting coveted forwarding wavelengths [36]. Switch overing velocities in these types of webs will finally be limited by the tuning velocity of the TL. To maintain operating expense respectable tuning times of the order of nanoseconds and below will be required [31, 39] .

Tunable Laser demand is expected to turn quickly at a compound one-year growing rate of 37 % over the following five old ages [40] . This market growing is being driven by WDM in long haul webs, with the transmutation of point-to-point optical webs to agile webs utilizing ROADMs [41] , and in metro webs. In the undermentioned chapter we look at the engineering that allows the tunable wavelength functionality that is necessary in TLs.

Tunable Lasers

Chapter 2 is concerned with tunable optical masers (TLs) for usage in current and future DWDM systems as examined in Chapter 1. The TL applications and chief demands in such systems are presented. The basic tuning mechanisms and strategies are introduced for a generic tunable optical maser. The execution of this tuning map in individual wavelength electronic TLs is discussed. This treatment is carried frontward to research widely tunable electronic Thallium with peculiar accent on the sampled grate distributed Bragg reflector optical maser.

2. 1 Applications of Tunable Lasers

Research, development and deployment of TL engineering has been ongoing for some clip now [1]. The application of TLs in increased capacity optical telecommunications systems has driven much of the involvement. Single frequence optical maser rectifying tubes with tunable wavelength functionality are of import constituents in current and future wavelength multiplexed optical communicating systems. The usage of TLs in the countries of consistent optical communicating, feeling and measuring is besides of involvement. These applications are nevertheless outside the

range of this thesis, which is focused on the usage of TLs in WDM systems.

2. 1. 1 Sparing and Inventory Reduction

The most obvious application of TLs in current DWDM systems, where increasing Numberss of wavelength channels are being used, is every bit optical beginnings to replace single fixed frequence DFB optical masers. This will cut down costs and better simpleness of fabrication and operating DWDM systems. By utilizing the TLs it will be possible to cut down stock list, as a individual TL merchandise will be capable of operating at any wavelength required. Similarly it will non be necessary to maintain a trim optical maser for each wavelength channel in the event of a optical maser weakness, therefore cut downing saving costs.

2. 1. 2 Wavelength Routing

Some of the more interesting applications of TL engineering are in the country of optical shift, routing and networking. TLs will be built-in constituents in the future optical routing and networking architectures. In these strategies the information transmitted over the web will be encoded onto finish dependent wavelengths. The information will be routed to the desired location utilizing inactive wavelength selective filtering, such as NA-N AWG. The ultimate end of such webs is to execute routing for each package of informations. A Thallium could be used to bring forth a coveted wavelength for each package to be transmitted, necessitating TLs with tuning times of nanoseconds or less [2] .

2. 1. 3 Reconfigurable Optical Add-Drop Multiplexer

Reconfigurable OADMs (ROADMs) [3] are tunable OADMs capable of altering the wavelengths dropped and added to a set of DWDM signals on a fiber. They allow for the dynamic provisioning of wavelength channels as they can be remotely tuned to alter the capacity dropped and added to each node, which will do webs more manageable and scaleable. The chief functionality, of channel multiplexing and demultiplexing, is performed by tunable filters. However as the added wavelength is unknown in progress TLs will be needed to let transmittal on the wavelength desired.

2.1.2 Wavelength Converters

Tunable Wavelength Converters (WC) are critical elements in province of the art and future DWDM webs [4]. The ability to change over a high information rate signal from any input wavelength channel to a tunable end product wavelength channel is an of import characteristic for increasing web flexibleness, leting informations to be routed along different waies in the web. There are assorted attacks to executing transition ; from opticalelectronic-optical (OEO) WCs which detect the signal before retransmission on the new wavelength, to all optical WCs, which use optical nonlinearities of certain stuffs to optically modulate the new wavelength [4, 5].

Each method requires a local optical maser to put the new wavelength that the signal is converted to. To accomplish tunable wavelength transition hence, it is necessary to hold a TL to move as the local optical maser. Wavelength convertors are of import elements in optical shift. In WDM most of the shift to link webs is wavelength exchanging. Tunable wavelength

convertors can be combined with NA-N AWGs to organize non-blocking optical wavelength switches.

The specific public presentation demands that tunable optical masers must run into for usage in DWDM systems will change from one application to the following. In general, though, they should give the same public presentation as fixed wavelength individual manner optical masers presently in usage in DWDM systems (e. g. distributed feedback optical masers) along with the added wavelength tuning functionality. The tunable optical maser demands of primary concern for TLs are outlined in Table 2. 1 [6, 7].

2. 2 Generic Laser Tuning

The wavelength tuning operation of a generic optical maser rectifying tube as described in [8] and [9] is presented in this subdivision. By mentioning to the basic optical maser spectra it is shown how the optical maser emanation wavelength can be tuned by seting the pit addition curve and/or the longitudinal manner places.

Basic Laser Structure

As current is injected into the active bed of a simplified optical maser, as shown in Figure 2. 1, bearers are ab initio converted to photons by selfgenerated emanation. Mirror contemplation at the pit ends is used to reflect the photons back into the active part for elaboration by stirred emanation – bring forthing photons of the same wavelength and stage, which in bend are amplified. The steady province status required for lasing to happen Begins when the pit roundtrip addition reaches integrity. This happens when the wavelength dependent manner addition, given by the optical parturiency (I") of the active medium addition (tabun) , overcomes the internal losingss ($I\pm i$) and the mirror losingss ($I\pm m$) , giving the addition status,

Above this addition threshold any extra injected bearers are converted straight to photons by stirred emanation. This gives the amplitude status that defines the lasing government of the optical maser, the pit roundtrip addition characteristic,

represented diagrammatically in Fig 2. 2 (a) . The phase status of the pit, dependant on the pit length L and the effectual refractile index n , is represented by,

for the Nth manner centred at wavelength i?¬N. This defines a set of longitudinal pit manners, as shown in Fig 2. 2 (B) , with manner spacing i? ¬m, at which lasing can happen if the addition status is met. The optical maser wavelength is determined by the longitudinal manner closest to the addition extremum, I» p, of the pit addition characteristic. In the instance illustrated in Fig. 2. 2 (degree Celsius) , which is typical of a Fabry Perot (FP) Laser, the optical maser emanation wavelength is centred at I» N with side manners transporting a important sum of the entire optical maser power. Single manner operation can be achieved by doing the mirror loss wavelength dependant (as is outlined in subdivision 2. 3) .

The optical maser end product wavelength can be tuned by changing the amplitude status – spectrally switching the peak I» p of the pit addition characteristic ; by changing the stage status – spectrally switching the longitudinal comb manners ; or by a combination of both these methods. The

tuning method used will impact the type of tuning achieved, giving https://assignbuster.com/use-of-fast-wavelength-tunable-laser-modulesessay/

uninterrupted tuning, discontinuous tuning or quasi-continuous tuning. It is of import to maintain other optical maser parametric quantities such as side manner suppression ratio (SMSR) and end product power every bit changeless as possible during wavelength tuning.

Continuous Tuning:

The optical maser wavelength is tuned swimmingly in little stairss staying at the same longitudinal manner throughout the tuning scope. Coincident control of the pit addition peak wavelength and the comb manner spectrum is required. By maintaining other optical maser parametric quantities constant throughout tuning while keeping the same dominant longitudinal manner the tuning scope is limited to around 15 nanometers.

(a) Cavity gain characteristic spectrum (B) Longitudinal manner spectrum,

(a) Cavity gain characteristic spectrum (B) Longitudinal manner spectrum,

(degree Celsius) Longitudinal optical maser emanation spectrum

Discontinuous Tuning:

If the optical maser is non confined to the same operational manner the wavelength can be tuned across the longitudinal manners of the optical maser. This manner hopping allows for an drawn-out tuning scope, up to around 100 nanometer, which is determined by the tuning scope of the pit addition characteristic. However with this strategy it is non possible to entree every wavelength in the scope.

Quasi-continuous Tuning:

This tuning strategy involves the merger of a figure of overlapping

continuously tunable scopes. Therefore, by utilizing manner skiping with https://assignbuster.com/use-of-fast-wavelength-tunable-laser-modules-essay/

uninterrupted tuning within each manner, a big tuning scope over which every wavelength is accessible can be achieved.

2. 2. 1 Cavity Gain Characteristic Tuning

The end product wavelength of the optical maser can be tuned by the spectral accommodation of the pit addition curve. This involves the motion of the addition extremum wavelength, I» p, by altering the wavelength dependance of the active medium addition, tabun, or by utilizing the mirror loss I" I» m as I» a wavelength selective filtering component, (refers to equation (2.2)).

Assuming no alteration in the comb manner spectrum the optical maser wavelength will alter by manner hops of I±m as I» p is varied. This consequences in discontinuous distinct tuning as shown in Fig. 2. 3 (a) . However review of the end product emanation spectrum shows that the issue is more equivocal, as the wavelength is tuned across different manners.

(a) Laser wavelength as a map of I» p displacement (B) Laser emanation spectra at indicated I» p places (a) Laser wavelength as a map of I» p displacement (B) Laser emanation spectra at indicated I» p places

The SMSR varies during tuning due to the fluctuation in the addition difference between the dominant manner and the 2nd strongest manner. This wavelength ambiguity is illustrated utilizing the markers x, y and omega in Fig. 2. 3 for the manner passage from I» N to I» N-1. The best suppression is given when I» p coincides with one of the comb manners, ab initio I» N, place ten. The addition difference between the two viing manners https://assignbuster.com/use-of-fast-wavelength-tunable-laser-modules-

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lessenings, until the eventual laterality of the following manner ; it so begins to increase until I» p coincides with mode I» N-1, place omega. The lowest suppression value is given at the manner hop boundary, place Y. This tuning method is finally limited by the tuning scope over which I» p can be tuned.

2. 2. 2 Comb Mode Spectrum Tuning

The optical maser wavelength can besides be tuned by switching the comb manner spectrum. With mention to equation (2.3) this can be achieved by either altering the length (L), or by altering the effectual refractile index (n), of the optical maser pit. Within the wavelength scope of involvement all the comb manners can be regarded as holding an equal spectral displacement. Assuming no alteration in the pit addition peak the wavelength will alter as the comb manner spectrum, I» c, is varied as shown in Fig. 2. 4, positional markers x, y and omega are used once more for illustration. At place x the comb manner is positioned such that manner N is in line with I» p. As the comb is shifted, the wavelength alterations in a uninterrupted additive manner up until place Y. The optical maser so jumps manner to the neighbouring manner, N+1, ensuing in a wavelength displacement downwards equal to the manner spacing breadth. As the comb continues switching the wavelength increases until it reaches omega, where manner N+1 is in line with I» p. The tuning continues in this manner giving periodic uninterrupted wavelength governments of width I" I» m, centred at the initial starting wavelength, I» N, but in turn leaping manner after every period, doing manner ambiguity. This happens in such a manner that each old period of uninterrupted tuning impetus is cancelled out. The same SMSR

jobs associated with tuning of the pit addition curve are apparent from Fig. 2.

(B). Therefore acceptable uninterrupted tuning is merely possible over a little wavelength scope, i. e. a fraction of I" I» m.

(a) Laser wavelength as a map of I» c displacement (B) Laser emanation spectra at indicated I» c places (a) Laser wavelength as a map of I» c displacement (B) Laser emanation spectra at indicated I» c places

2.2.3 Combined Tuning

To accomplish tuning public presentation that is superior to that already described, coincident control of both the pit addition extremum and the comb manner spectrum is required. By tuning the comb manner spectrum by the same sum as the pit addition extremum (i. e. I" $I \gg p = I" I \gg c$) it is possible to accomplish a comparatively wider tuning scope. This strategy, as depicted in Fig. 2. 5 (a) , offers uninterrupted tuning with fixed SMSR over the full scope. The tuning scope will be determined by the smaller tuning scope of $I \gg p$ or $I \gg c$, by and large being limited by the latter, which is still slightly larger than the uninterrupted tuning scope described in subdivision 2. 2. 4, which is a fraction of $I" I \gg m$.

This scope can be farther increased by taking a quasi-continuous tuning attack.

As earlier I" I» p is monotonically increased while I" I» c is changed in a stepwise mode over I" I» m, so being reset to its initial value, ensuing in a manner leap to a lower manner. The end product wavelength increases tuning

swimmingly as in the uninterrupted strategy with fixed SMSR but mode leaps are permitted after each longitudinal manner. This periodic manner skiping nevertheless introduces ambiguity in footings of stage and wavelength around the manner boundaries, as shown in Fig. 2.5 (B). The emanation spectrum is the same before the manner hop and straight after, despite the fact that the dominant manner has changed from manner N to mode N-1. This prevents the usage of this strategy for certain applications such as consistent optical sensing, nevertheless it offers the widest tuning scope and is hence attractive for usage in WDM applications.

Laser emanation spectra utilizing combined tuning for (a) uninterrupted

tuning, and (B) guasi-continuous tuning Laser emanation spectra utilizing

combined tuning for (a) uninterrupted tuning, and (B) guasi-continuous

As seen above, in an FP optical maser more than one manner reaches the lasing status, ensuing in a multimode emanation spectrum. This is due to the broad spectral addition and the narrowly separated longitudinal manners of the pit. Single manner operation is required for DWDM systems as chromatic scattering and SMSR are issues of concern. One of import method to accomplish individual manner operation is by utilizing shorter pits to increase the manner spacing so that merely one manner falls under the addition curve, as in the perpendicular pit surface breathing optical maser (VCSEL). But the most widely used method is the usage of periodic corrugated constructions to supply manner selectivity.

In the FP optical maser mirror losingss are wavelength independent and the spectral emanation will dwell of the manners that experience net addition, determined by the broad addition curve. The manner choice filtering can be enhanced by utilizing periodic constructions to make wavelength dependent mirror loss (I» m in equation 2. 2) to stamp down all the manners except the manner selected for lasing, therefore supplying mode choice filtering as displayed in Fig. 2. 6. In a wave guide with a sporadically changing index grating the contemplation coefficients for the different manners will be wavelength dependent. Distributed feedback occurs near the wavelength for which all the feedback or contemplations from the grating attention deficit disorder in stage. This is defined as the Bragg wavelength,

where I> is the grating pitch and n is the effectual refractile index. The manner closest to the Bragg wavelength (I>B) will be reflected constructively as the contemplations are in stage. For the manners off from I>B the contemplations will be out of stage and the manners will be suppressed. This consequences in individual manner contemplation at the I> B leting for lasing at this manner merely [10].

Laser emanation utilizing mode selective filtering centred at Bragg wavelength I» B Laser emanation utilizing mode selective filtering centred at Bragg wavelength I» B

2. 4 Electronic Tunable Lasers

It has been shown that the lasing wavelength for a optical maser can be tuned by changing the stage status and/or by changing the amplitude status. From equation 2. 3 stand foring the stage status it can be seen that the comb manner places can be spectrally shifted by changing the physical length (L) or by changing the effectual refractile index (n) of the optical maser pit. To accomplish fast tunability it is non executable to physically set L as the clip required for mechanical (used in external pit optical masers) or electromechanical (as used in VCSELs) tuning will be limited to the order of msecs. A waveguide subdivision of length L with an electronically governable n could work as a suited tuning component.

With respects to the amplitude status a Bragg grating reflector can be used to give wavelength selective loss so that lasing occurs merely at the wavelength of minimal loss – the Bragg wavelength (I» B). Mentioning to equation 2. 4 the grate pitch of the reflector (I>) can non easy be dynamically changed as it is set at fiction. However it is possible to tune the I» B by electronically commanding the effectual refractile index of the grate.

This attack could potentially give a TL with sufficiently short tuning clip for optical shift applications. To electronically tune the end product wavelength hence, it is necessary to change the refractile index of a stage component and/or an amplitude component. Refractive index tuning can be achieved in semiconducting materials by field effects, thermic control and bearer injection.

2. 4. 1 Refractive Index Tuning

The application of an electric field can be used to alter the refractile index of a stuff, as used for Mach-Zehnder transition (introduced in subdivision 1. 3.

2). This electro-optic consequence, although capable of high velocity

tuning, can merely give a little index displacement [11] . Therefore

restricting the tuning scope accomplishable and doing it unsuitable for DWDM TL applications. Thermal control can besides be used for wavelength control, as refractile index additions with temperature [12]. Although offering a comparatively better tuning scope inordinate warming will finally restrict the scope accomplishable. The tuning velocities will besides be limited to microsecond clip graduated tables due to thermic electric resistance.

Carrier injection is the most often used method to command the refractile index of a semiconducting material wave guide for wavelength tuning, giving the largest index displacement at nanosecond timescales [9]. Carriers injected into the wave guide by an external current beginning cut down the effectual index in proportion to the extra bearer denseness, giving an effectual index alteration (I" n) approximated by,

where _ is the optical manner parturiency factor, _ is the index alteration per bearer denseness and N is the injected bearer denseness [13] .

In the instance of a Bragg reflector, bearer injection reduces the effectual index giving the Bragg wavelength (I» B) a negative wavelength displacement, harmonizing to equation 2. 4. For I» B to remain at this wavelength the current beginning must be sustained at the appropriate degree, or changed for a different wavelength displacement. The wavelength tuning scope of I» B will be limited by the sum of effectual index alteration achievable in the grate,

The index alteration becomes less efficient at big injection current degrees

as nonradiative recombination additions at higher bearer densenesss. The https://assignbuster.com/use-of-fast-wavelength-tunable-laser-modules-essay/

tuning scope will besides be limited by inordinate warming of the optical maser due to the sustained current injection. Besides impacting optical maser parametric quantities such as power and threshold current the warming will besides do a parasitic refractive index addition that will antagonize the bearer injection index alteration to a certain extent.

2. 4. 2 Distributed Feedback (DFB) Laser

The distributed feedback (DFB) optical maser combines an active and gravelly part over the length of the optical maser pit. It was developed as a fixed wavelength individual manner optical maser, now being one of the most prevailing, and was non originally intended for reasonableness. The cross integrating of the wavelength selective and addition functionality, as shown in Fig. 2. 7, allows for comparatively simple fiction with no active/passive interface. Merely wavelengths around the Bragg wavelength are reflected back into the pit and so this is the lone scope of visible radiation that builds up within the active bed and reaches the lasing threshold.

Distributed Feedback (DFB) Laser Schematic Distributed Feedback (DFB) Laser Schematic

Some of the first TLs were DFB based with the electrode split into two or three tuning subdivisions. The operation of these devices is complicated and wavelength control is hard while offering merely modest tuning scopes of ~3 nm [13, 14] . The usage of thermally controlled DFBs as TLs is more common, offering a stable modehop free, easy governable wavelength tuning based on dependable standard DFB engineering. As the emanation wavelength of a DFB alterations by about 0. 1 nm/oC [12] , a tuning scope of 3-4 nanometer is possible with a temperature tuning of 30 – 40 oC.

To offer wider tuning scopes assorted component sellers have developed selectable arrays of 8 – 12 DFB optical masers which can run at any wavelength across the C-band or big parts of it. Either optical yoke [15, 16] or an external micro-ectromechanical

(MEM) mirror [17] is used to end product the operating wavelength of the array. Using DFBs with different grating periods (_) to give different default end product wavelengths separated by ~3nm it is possible to cover the C-band with a thermally controlled 12 DFB array. The chief drawback of utilizing arrays is the power loss associated with the coupling option or the traveling portion associated with the MEM mirror option. Besides the slow tuning times reported, measured in seconds, limit their usage for future dynamic functionality.

2. 4. 3 Distributed Bragg Reflector (DBR) Laser

The development of distributed Bragg reflector (DBR) optical masers with separate active and inactive parts was originally, as with DFBs, for fixed wavelength individual frequence operation, but in comparing DBRs are better suited than DFBs for wavelength tunability. This is because of the built-in active/passive separation of the addition map and the wavelength or manner selective map in the DBR, therefore cut downing the influence of the wavelength tuning on the addition functionality. The most of import DBR optical maser, a three-section device with a inactive wave guide part separated from the active part is illustrated in Fig. 2. 8. A Bragg grate etched into the wave guide at one terminal of the device operates as a inactive wavelength selective mirror. Anti contemplation (AR) coating is used at this terminal of the device to cut down contemplations at the terminal of the grate. The cleaved aspect provides the mirroring at the other terminal of the device. A inactive stage control subdivision separates the grating subdivision from the active subdivision, which provides the optical addition. The inactive part is fabricated with a higher bandgap stuff than the active part to forestall photon soaking up in the stage and grating subdivision. This allows for current injection bearer denseness alteration in the inactive part without interfering with the photon coevals of the active part, therefore leting for the close independent control of the optical addition and wavelength.

Distributed Bragg Reflector (DBR) Laser Schematic Distributed Bragg Reflector (DBR) Laser Schematic

Currents applied to each subdivision control the optical maser operation. The current to the addition subdivision, IA, controls the optical end product power. The pit addition peak wavelength of the narrowband contemplation, which can be approximated good by the Bragg wavelength [18] , is controlled by current injection IB into the Bragg grate. The longitudinal comb manner places can be aligned with the Bragg extremum by current injection to the stage subdivision, IP. In this manner the optical maser wavelength can be fine-tuned, giving better SMSR. Using coincident control of the stage subdivision and grating subdivision it is possible to accomplish uninterrupted tuning scopes of ~4 nanometer and quasi-continuous tuning scopes of ~10 nm [19] . A tuning scope of 17 nanometers utilizing discontinuous tuning was achieved in [20] .

https://assignbuster.com/use-of-fast-wavelength-tunable-laser-modulesessay/ DBR optical masers are suited TLs for many telecom applications ; based on mature engineering they offer dependability and efficiency with high end product powers and fast tuning times. However even at record tuning scopes they can still non offer full C-band coverage. Ultimately the tuning scope of the DBR will be limited by the extent to which the Bragg wavelength can be tuned – this will be determined by the maximal accomplishable index alteration in the grate subdivision,

and when utilizing bearer injection is limited to \sim 5 % [7] .

2. 4. 4 Widely Tunable Lasers

Due to the restriction of the refractile index accomplishable in a wave guide, the tuning scope of a device based on such a alteration will be limited to around ~15 nm. This is in contrast to the wide addition curve of semiconducting material stuffs and the EDFA magnifying bandwidth. For DWDM systems it is desirable to hold a individual device which can offer at least full C-band coverage. To accomplish broad tunability it is necessary to be able to alter the comparative index, and therefore the comparative wavelength, by a multiple of the sum that any individual wave guide index can be changed. This can be achieved by altering an index difference as opposed to the index itself. Assorted devices capable of this broad tuning can be structurally arranged into the undermentioned groups.

Interferometric Structures:

Lasers based on MZ interferometry can offer widen tuning scopes by utilizing a semi-MZ interferometer apparatus or a ' Y ' construction. The longitudinal manners from two pits of different lengths interfere constructively and destructively at the Y junction to give individual manner operation. The end product wavelength can be tuned byvarying the refractile index of one or more of the pits. Y-branch optical masers and vertical-Mach-Zehnder optical masers are illustrations of this engineering. Since these devices do non incorporate a grate construction their fiction is slightly simplified. This nevertheless besides limits the side manner filtrating giving low SMSR. A particular instance of this group is the modulated grate Y-branch (MGY) optical maser in which inactive subdivisions with modulated grates are used. The grates have different comb contemplation spectra which can significantly better manner selectivity, giving SMSR of 40 dubnium over a tuning scope of 40 nm [21] .

Co-directional Coupler Structures:

The usage of co-directional matching between two wave guides can be used to filtrate out a individual longitudinal pit manner. The difference in refractile index of two wave guides allows for an enhanced tuning scope. In the grate assisted perpendicular coupling filter optical maser [22] two wave guides are vertically stacked with a grate placed on the upper wave guide which gives matching at the Bragg wavelength. The optical maser can be tuned by bearer injection into the gravelly subdivision. The tuning scope is relative to the passband of the filtering and so in accomplishing a broad tuning scope manner choice will be compromised, taking to reduced SMSR.

This status is improved in the grate assisted co-directional coupling with sampled reflector (GCSR) optical maser by utilizing a 2nd filtering component. A 2nd grate with a modified comb like contemplation spectrum is placed at the back terminal of the optical maser. The contemplation https://assignbuster.com/use-of-fast-wavelength-tunable-laser-modulesessay/ extremums are narrow plenty to go through merely one pit manner while the co-directional yoke filters out merely one extremum. In this manner a wider tuning scope can be achieved with coarse tuning performed by the original grate and all right tuning performed by the sampled grate. A 74 nanometer tuning scope with good SMSR was achieved utilizing this design in [23] . A disadvantage of this optical maser is the complex fiction procedure involved, due to the usage of different wave guides and two grate subdivisions.

Grating Based Structures:

These constructions operate on the same rule as DBR and DFB optical masers, in that grating contemplation is used to choose out a longitudinal pit manner for lasing. The tuning scope is increased by utilizing two separate grates in the optical maser construction. The grates are modified to give comb like contemplation spectra, with each grating holding somewhat different comb spacing. By tuning one mirror relation to the other it is possible to accomplish a Vernier tuning sweetening. Devicess based on this engineering offer tuning scopes of over 40 nanometers with high SMSR degrees.

A optical maser from this group, the sampled grate distributed Bragg reflector (SGDBR), is the topic of experimental work in the undermentioned chapters and so will be explained in greater item in the undermentioned subdivision, along with an lineation of other optical masers in this group.

2. 5 Widely Tunable Grating Based Tunable Lasers

In a standard DBR optical maser as presented in subdivision 2.4.3

wavelength tuning is performed by changing the Bragg wavelength of a https://assignbuster.com/use-of-fast-wavelength-tunable-laser-modulesessay/

individual grate subdivision to set the contemplation window of minimal pit loss. A stage subdivision was so used to put a manner at the Centre of this window. In this strategy the tuning scope is limited by the sum that the Bragg wavelength can be varied. It was foremost proposed by Coldren in [24]] that this restriction could be overcome by utilizing the fluctuation in the whipping between the contemplation spectra of two multi component mirrors. The contemplations of which, have periodic upper limits, with the upper limit otherwise spaced in each. This Vernier tuning sweetening is illustrated in Fig. 2. 9 utilizing two contemplation spectrums, R1 and R2, with the comb upper limit or extremums spaced by different sums. Due to the different extremum spacing used merely one set of contemplation extremums can be in alliance at any one clip, within a broad scope, to give an overall contemplation R1. R2. By switching the comb place of R2 by a little sum R2 a different set of peaks come into alliance. The new point of alliance is a comparatively big distance off, R1R2, from the original point of alignment – therefore by changing the comb places of one of the contemplation spectrums relative to the other, a little alteration in the comb places gives a big alteration in the combined contemplation.

Vernier Tuning Enhancements

2. 5. 1 Sampled Grating Distributed Bragg Reflector (SGDBR)

A method to integrate this tuning sweetening utilizing multi component mirrors, in the signifier of the sampled grate distributed Bragg reflector (SGDBR), was proposed in 1991 [25, 26] and foremost demonstrated shortly after in [27, 28]. The SGDBR, as illustrated in Fig. 2. 10, has two sampled grating mirror subdivisions, with comb like contemplation spectra,

etched into the wave guide at either terminal of an active addition subdivision and inactive stage subdivision. Its structural similarity to a conventional DBR optical maser is evident. Sampled Grating Distributed Bragg Grating (SGDBR) Laser Schematic

The SG mirror is basically a standard DBR mirror with grating elements blanked out in a periodic mode. In Fig. 2. 11 a grate with the pitch (I>) set to give Bragg contemplation at 1550nm is sampled with a sampling period LS and a grate length LG to give the sampled grate construction of length L= NSLS, where NS is the figure of samples used. Sampled grates are fabricated in a similar method to conventional Bragg grates with merely the excess measure of utilizing lithography to try the gratings. Sampled Grating Schematic

The SG has a comb shaped contemplation spectrum with narrow extremums spaced around a Centre extremum which is at the Bragg wavelength [29, 30] . These side extremums occur where the contemplation from the single grates are in stage which happens at wavelength separated by,

where nanogram is the group refractile index in the stuff [31] . The extremum amplitudes are unequal, with the contemplation strengths symmetrically cut downing from the Centre wavelength. The full moving ridge half upper limit (FWHM) of the axial rotation off envelope is a good step of the useable contemplation extremums and is about equal to

[31].

Using a lower responsibility rhythm of grating length to trying length will give a wider axial rotation off envelope. However as can be seen from work carried out on sampled grating coefficient of reflection in [32] (reproduced in Fig. 2. 12) maintaining the same sampling period but cut downing the grating explosion length reduces the contemplation peak amplitude from each grating subdivision. So a trade off is needed between tuning scope, contemplation amplitude and bit length. In [7, 29] responsibility rhythms of 6-10 % have been used in sampled grates of lengths of ~500 l? m made up of 10 and 13 samples respectively. Simulated contemplation spectra of sampled grates of unvarying length but with different responsibility rhythms. [32]

In the SGDBR two sampled grate mirrors are used to supply comb molded contemplation from either terminal of the optical maser. Different trying periods are used in the grates to give a mismatch in the peak spacing of each grate, therefore leting merely one set of extremums to come into alliance within in the scope of involvement. The mirror loss seen by the propagating manners is the merchandise of the front mirror contemplation and the back mirror contemplation. The wavelength of peak alliance therefore experiences minimal mirror loss leting a manner placed at this wavelength to idle. Anti contemplation coating is applied to stamp down any contemplation from the grating terminals [33] .

As with the three-section DBR, the optical maser wavelength can be tuned by utilizing bearer injection to change the refractile index of the grate and stage subdivisions to tune the wavelength of minimal loss and the

longitudinal manner places, severally.

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Enhanced Vernier tuning can be achieved in the SGDBR by changing the contemplation combs comparative to each other.

Through utilizing the same grate pitch (I>) in both mirror sections the comb contemplations are centred at the same Bragg wavelength as seen in Fig. 2. 13 (a). With no current applied to the mirror subdivisions, lasing can happen at this wavelength. The stage subdivision can be used to ticket tune the longitudinal manner to the Centre of the contemplation window. The combined coefficient of reflection of the comb extremums, R1. R2, is shown in Fig. 2. 13 (B) . Discontinuous tuning over a broad tuning scope can be achieved by tuning one of the mirrors relative to the other. By tuning the contemplation R2 to a higher wavelength by I" I» m (the mismatch in extremum spacing between the two mirror contemplations) the peak alliance will leap to the following extremum or ace manner. This differential tuning choices out widely infinite longitudinal manners and can be continued across the tuning scope in either way. The maximal extremum spacing is set less than or equal to the available direct index tuning of the mirror subdivisions to enable tuning to wavelengths between the contemplation extremums. This is possible by tuning both mirror subdivisions at the same time to maintain the same peak alliance. This manner tuning choices out closely separated adjacent longitudinal manners and can be used in a stepwise mode to tune to manners between the contemplation extremums across the tuning scope. The stage subdivision is used throughout to guarantee that the manners are positioned at the Centre of the contemplation window. The tuning sweetening achieved is given by,

where, F is the mean peak spacing of the two mirrors (I" I» s, ave) divided by the extremum spacing mismatch I" I» m.

Typical power vs. wavelength secret plans of (a) single contemplations from both mirror subdivisions R1and R2, (B) combined contemplation of both mirror subdivisions, i. e. R1. R2 and (degree Celsius) single contemplations from both mirror subdivisions R1and R2 at greater declaration. Typical power vs. wavelength secret plans of (a) single contemplations from both mirror subdivisions R1and R2, (B) combined contemplation of both mirror subdivisions, i. e. R1. R2 and (degree Celsius) single contemplations from both mirror subdivisions R1and R2 at greater declaration.

Mode suppression is an issue that influences the tuning scope accomplishable in the design of an SGDBR. Suppression of next longitudinal manners is of less concern than that of next super-modes. Due to the narrow contemplation peaks the former can be sufficiently reduced by the alliance of the comb extremums, through mirror control, and the lasing manner place through phase subdivision control. The ulterior nevertheless can be debatable and their suppression will restrict the tuning scope.

Mentioning to equation (2.9), increasing the tuning scope sweetening (F) is possible through decrease in the extremum spacing mismatch (I" I» m). This will nevertheless cut down the SMSR due to the increasing convergence of the extremums next to the extremum of alliance. This is related to the repetition manner spacing (I" I» RMS), marked in Fig. 2. 13 (a) as the distance between which contemplation extremums are aligned, and will by and large restrict the maximal tuning scope. When one of the contemplation

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combs is tuned by this sum relation to the other, a repetition manner can go the dominant wavelength due to its place under the stuff addition spectrum, ensuing in manner hopping across the wavelength scope to this manner. The SMSR will besides be significantly reduced due to lasing at both points of mirror alliance. Analytic looks for the loss difference between the lasing manner and the assorted side manners have been derived in [29] . If tuning scope is of primary concern F can be increased at the disbursal of quasicontinuous tuning across the scope. This can be done by puting the peak spacing of the mirror subdivisions greater than the available direct index tuning of the grate. A discontinuous tuning scope of 72 nanometer was reported in [34] .

Inter-ferometric optical masers and co-directional conjugate optical masers by and large have greater end product powers than the SGDBR for a given thrust current due to the placement of the active addition subdivision at the forepart of the optical maser construction. In the SGDBR the optical end product power from the addition subdivision is reduced by bearer induced soaking up losingss in the inactive forepart mirror subdivision. This loss can increase for wavelengths at the border of the tuning scope which require high mirror tuning currents, taking to a power fluctuation across the scope for a fixed thrust current of ~6 dubnium. This fluctuation can be reduced and end product powers can be increased by utilizing addition control during tuning and integrating of the optical maser with an SOA [34] .

With respects to the SOA integrating, the addition subdivision positioning in the SGDBR is advantageous in comparing to the other widely tunable

leasers, necessitating no forepart aspect contemplations for operation. This https://assignbuster.com/use-of-fast-wavelength-tunable-laser-modules-essay/

allows for massive integrating of the SGDBR and SOA with merely minimum addition in fiction complexness. Fibre coupled powers of 13 dBm (20 mW) have been reported for packaged devices offering full C-band or L-band coverage with high SMSR [35] . Component integrating has expanded beyond run intoing the power concerns to include the integrating of electroabsorption modulators and MZ modulators [36, 37] . This has allowed for the development of low-cost, low-size and low-power individual bit sender and wavelength convertor photonic integrated circuits [38] .

2. 5. 2 Super Structure Grating Distributed Bragg Reflector (SSGDBR)

The usage of sampled grate constructions is the simplest method to accomplish comb like contemplation spectra. The sampled grates nevertheless do non possess the optimal " top chapeau like " contemplation of equal extremum power within a limited bandwidth and no extremums outside that bandwidth ; alternatively they have non unvarying contemplation extremums with power cut downing symmetrically around a Centre extremum. Super construction grates (SSG) utilizing a frequence or phase transition instead than an amplitude transition give improved contemplation spectra and are used in ace construction grating distributed Bragg reflector (SSGDBR) lasers [39] . This allows for improved tuning operation and more leveled end product powers across the tuning scope. The SSGDBR is structurally similar to the SGDBR with the lone difference being the different grate design. The frequence varied grates give contemplation spectra with close unvarying extremum magnitude across a chosen scope and significantly reduced contemplation outside this scope. Higher

coefficient of reflection is besides achieved, in comparing to try grate contemplations, as the grate covers the whole tuning component. These betterments nevertheless are at the disbursal of increased fiction complexness for the grates. Discontinuous tuning of over 100 nm [40] and quasi-continuous tuning over 62 nm [41] with good SMSR has been reported.

2. 5. 3 Digital Super-mode Distributed Bragg Reflector (DSDBR)

The digital super-mode distributed Bragg reflector (DSDBR) optical maser is a 4 subdivision device similar to the SGDBR with a addition subdivision and a stage subdivision but with different forepart and back mirror subdivisions. A stage grate is used in the back mirror to supply a comb contemplation. This is basically a unvarying grate separated by stage displacements to accomplish improved contemplation, over the sampled grate, with a fixed figure of extremums with equal strength and spacing [42] . The front mirror is a continuously chirped grating with relativity low contemplation across the full tuning scope. Eight short electrical contacts are positioned on the mirror for current injection into different subdivisions of the grate.

By commanding the current to neighbouring contacts on the forepart mirror the contemplation is enhanced over a wide wavelength scope. This enhancement extremum scope is set at ~7 nanometer to guarantee it overlaps with merely one extremum from the back mirror contemplation. In this manner the front mirror can supply class or super-mode wavelength tuning. The strong, narrow rear contemplation extremums guarantee individual manner operation, while the stage subdivision is used for finetuning of the longitudinal manner places. Quasi-continuous tuning can be https://assignbuster.com/use-of-fast-wavelength-tunable-laser-modulesessay/ achieved by commanding all three subdivisions to give SMSR & gt ; 40 dubnium across a tuning scope of 45 nm [43] . Wavelength dependent losingss are reduced in the DSDBR, as merely little tuning currents are required to command the forepart mirror subdivision. High current truth is besides non necessary for the front mirror tuning as merely the rear mirror controls the manner choice. This decrease the figure of high truth tuning currents is nevertheless at the cost of an increased figure of overall control currents.

2. 5. 4 Widely Tunable Twin Guide Lasers

A disadvantage of the four-section DBR devices described above is the demand for control of three or more tuning currents to accomplish complete wavelength coverage. The wavelength tuning word picture and control can be simplified by a decrease in the figure of control currents, as is the instance in widely tunable twin usher optical masers. These optical masers are based on the distributed feedback tunable twin usher (DFB-TTG) optical maser [44] in which there is a cross electrical separation between the active and tuning subdivision that cover the length of the optical maser. As is the instance with the conventional DFB optical maser a stage subdivision is non needed, therefore cut downing the figure of control currents.

The sampled grate and ace construction grating tunable twin usher ((S) SG-TTG) optical masers are illustrations of such devices, with the former exhibiting quasi-continuous wavelength coverage with 10 mW end product powers and greater than 35 dB SMSR across 40 nm [45]. The tuning part is split into two subdivisions, with somewhat different grates in each, giving otherwise spaced contemplation combs. Vernier tuning is possible through https://assignbuster.com/use-of-fast-wavelength-tunable-laser-modulesessay/

differential and coincident control of the refractile index of both subdivisions. Single manner lasing is achieved at the wavelength of comb peak alliance with no extra stage control needed. Thus broad wavelength tuning can be achieved with merely two control currents (one current to each grating subdivision) and a changeless current to the active subdivision. A disadvantage of these optical masers is their transverse construction which is more complex than the longitudinal integrating of the four subdivision devices, taking to increased fiction costs.

Drumhead

This chapter has looked at semiconducting material tunable optical masers in footings of their chief applications in DWDM systems and the associated device demands. A reappraisal of the wavelength tuning of a generic optical maser was given, and more specific information was given on different assortments of TL semiconducting material devices. The undermentioned chapters are concerned with the usage of such devices in existent system faculties, and therefore screens device word picture and control, and by experimentation examines the impact of their usage, both when fixed and when tuning, on system public presentation.

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