Tunable optics technology and relative cost trends

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OUTLINE

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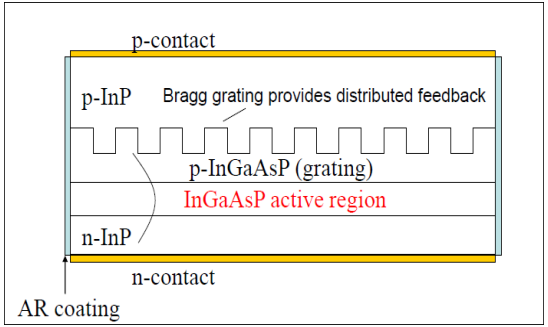
Motivations

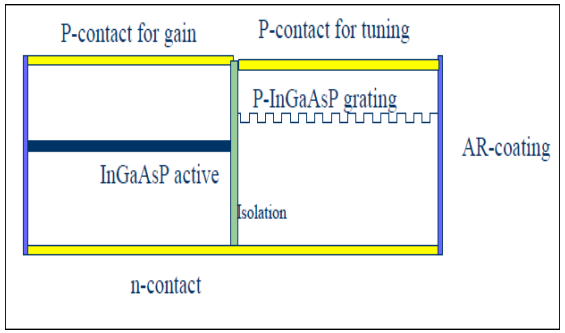
- **Achieving 10+Gbps per wavelength is facing great challenge**
  - High Device Cost , Fiber Dispersion Limit , Power Budget Decrease
  - OFDM or other high order modulation still not simple and cheap enough for access
  - Wavelength stacked TDM PONs could be a good choice
- **The key of protecting previous investment is to reuse ODN**
  - P-to-P WDM channels require wavelength distinguishing
  - Any changes to the ODN are labor-intensive, and service-disruptive
  - Current generation of fiber installations are expected to be in service for 20 -30 years
  - Therefore, to host multiple λs on the same splitter based ODN, a good way is to add tunable filter in Rx
- **To avoid inventory issues, tunable lasers are strongly recommended to be considered.**
  - Flexible wavelength management and capacity assignment

Introduction of DFB and DBR lasers

- A DFB laser diode can be tuned by changing the temperature by using TEC
  - As chip temperature changes, the index changes.
  - The lasing wavelength will change.
  - Tuning is about 0.1nm/C.
  - Tuning range is limited by operational temperature range,
  - The tuning range is about 3.0nm to 4.0nm.



Distributed Feedback (DFB) laser



Distributed Bragg Reflector (DBR) laser

- For DBR, laser wavelength depends on grating pitch and phase matching.
  - When current changes at the grating range, the index will change.
  - The lasing wavelength will change.
  - The maximum tuning range is around 8.0nm.

Source: Tunable Laser Technology: Fundamental and Overview , Santur Corporation

Comparison between DBR laser and DFB Laser

Laser type	Thermal DFB	DBR
Wavelength Tuning Range	4 * 100GHz	> 8 * 100GHz
Tuning Speed	Few ms	Few ns
Tuning Granularity	Continuous tuning	Continuous tuning
Laser Complexity	simple	medium

Remarks:

- Tunable DBR laser has advantages of wide tuning range, fast tuning speed, relatively high output power, etc.
- Thermal tuning DFB laser has moderate tuning range, and only supports slow wavelength tuning; but it has the advantage of high wavelength stability , low fabrication complexity and control simplicity, consequently low cost.

Cost Comparison

laser type[1]	Thermal DFB	DBR
Tuning Parameters	TEC	Grating Range Current @Phase Current
Chip Cost[2]	A	1.5 A
Package Cost[3]	B	1.2 B
Calibration Cost	C	C
Total Cost	D	1.3 D

Remarks:

1. Tunable DBR laser's fabrication processing is similar to that of DFB laser. The only difference is that DBR laser grating is on the passive section while DFB laser grating is on active section
2. DBR laser chip size is about twice of DFB laser. DBR laser yield is higher than DFB laser.
3. Considering that the package cost is the majority in total cost, the estimated cost of DBR will be a little higher than the cost of thermally controlled DFB.

Possible optical tuning filters

TYPE	IL(dB)	Isolation	BW(3dB)	Tuning Range(nm)	Tuning Speed	Tuning mechanism
F-P(PZT)	2dB	2nm/30dB	<0.5nm	~10nm	ms	PZT
F-P(Liquid-Crystal)	3dB	2nm/30dB	<0.5nm	~50nm	us	Crystal orientation
MEMS	1dB	2nm/30dB	<0.5nm	~60nm	ms	Micro machine
Cascaded MZI	$LiNbO_3$:19dB	0.4nm/22dB	<0.2nm	~4nm	50ns	Electro-Optic
	SiliCa:1dB					
FBG	0.1dB	1.6nm/22dB	<0.2nm	~10nm	2ms	Temperature Stretching

TYPE	IL(dB)	Isolation	BW(3dB)	Tuning Range(nm)	Tuning Speed	Tuning mechanism
AWG	8dB	0.8nm/30dB	<0.2nm	~40 nm	10ms	Thermally tuned
AOTF	4dB	4nm/30dB	~1.5nm	>60nm	us	Acousto-Optic
Tunable Ring Resonator filters	3dB	2nm/30dB	0.2nm	25nm	ms	Temperature

What kind of tuning optical filter in optical access network

- Wide Tuning Range

  c-band, ideally c+L band

- Narrow Bandwidth

  100GHz~200GHz

  50GHz~100GHz

- Low Insertion Loss

  The lower the better

- High Tuning Speed

  Classes of Channel Tuning Times (Ref.G.989.2)

  Class 1 < 10 μs
  Class 2 10 μs to 25 ms
  Class 3 25 ms to 1

- Less Crosstalk

Summary

- Tunable optics give considerable benefits to optical access network including ultra-broadband, spectrum flexibility, grouping arbitrary sets of ONUs etc.

- For tunable laser, the DBR has the advantage of wavelength tuning range, tuning speed, while thermally DFB has the advantage of fabrication, tuning simplicity and low cost.

- Low insert loss, narrow bandwidth , high tuning speed and wide tunable range optical filters are popular in access technology.

Thank you!