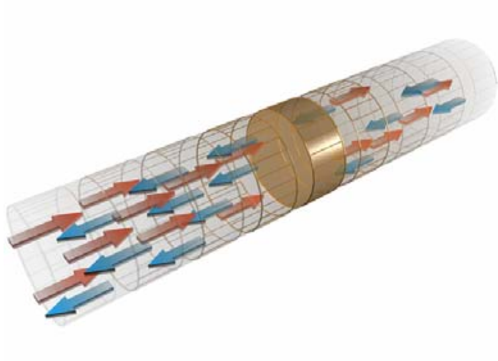
BOSA: High Resolution Optical Spectrum Analyzer based on Stimulated Brillouin Scattering

Abstract: the non linear interaction between two counter-propagating optical beams along an optical fibre can be cleverly used to obtain detailed spectral information about one of the beams. Stimulated Brillouin Scattering effect is used to derive a spectrum analyzer with 0.08 pm (10MHz) of resolution and 80 dB of dynamic range.

STIMULATED BRILLOUIN SCATTERING: Selective Amplification

When an optical beam with certain intensity, called pump, propagates through a material media a non linear effect, known as **Spontaneous Brillouin Scattering** (SBS), is produced. Due to SBS part of the incident light is backscattered. To assure the Brillouin Scattering to take place it is necessary a high optical intensity in the interaction medium. Such a situation is easily reached in standard optical fibres in which high power values can be injected in small areas.

When a second optical beam, called signal, is introduced in the fibres in a counter propagating way the non linear effect produced is known as **Stimulated Brillouin Scattering.** Under this situation the signal acts as a stimulus of the effect and the Brillouin scattering is intensified.



Particularly, the backscattered power in a given point z of the fibre is determined by:

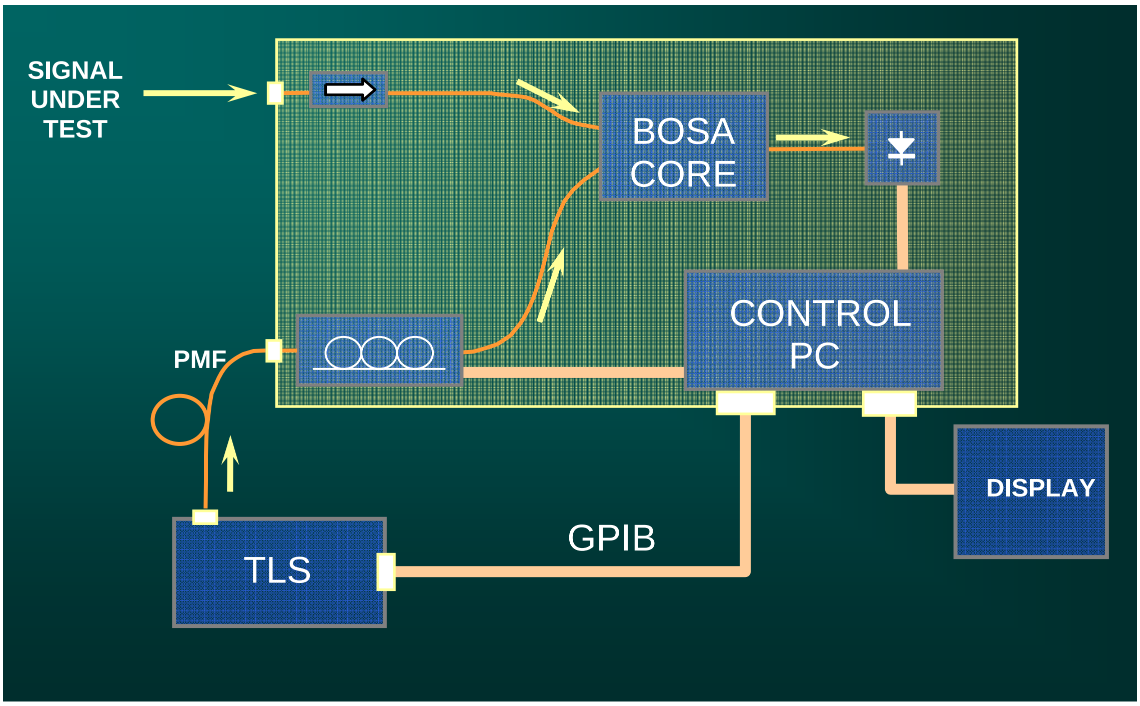
$$dP_B(z,\lambda) = \frac{g_B}{A_{ef}} P_P(z,\lambda_P) \cdot P_S(z,\lambda_P + \lambda_B) \cdot dz$$

where g_B is the Brillouin gain coefficient, A_{ef} is the effective area of the fibre, $P_P(z,\lambda_P)$ is the pump beam intensity in a point z of the fibre and $P_S(z,\lambda_P+\lambda_B)$ is the intensity of the amplified signal beam, in the same point, at the wavelength $\lambda_P+\lambda_B$ selected by the pump beam and the slight Doppler shift λ_B associated to the Brillouin effect.

The backscattered power is now directly determined by the power of the signal. The Brillouin scattering has selective wavelength behaviour and it is produced only in a narrow spectral range of 0.08 pm (10 MHz). By modifying the wavelength of the pump it is possible to amplify selected spectral components of the signal.

BOSA AND BRILLOUIN

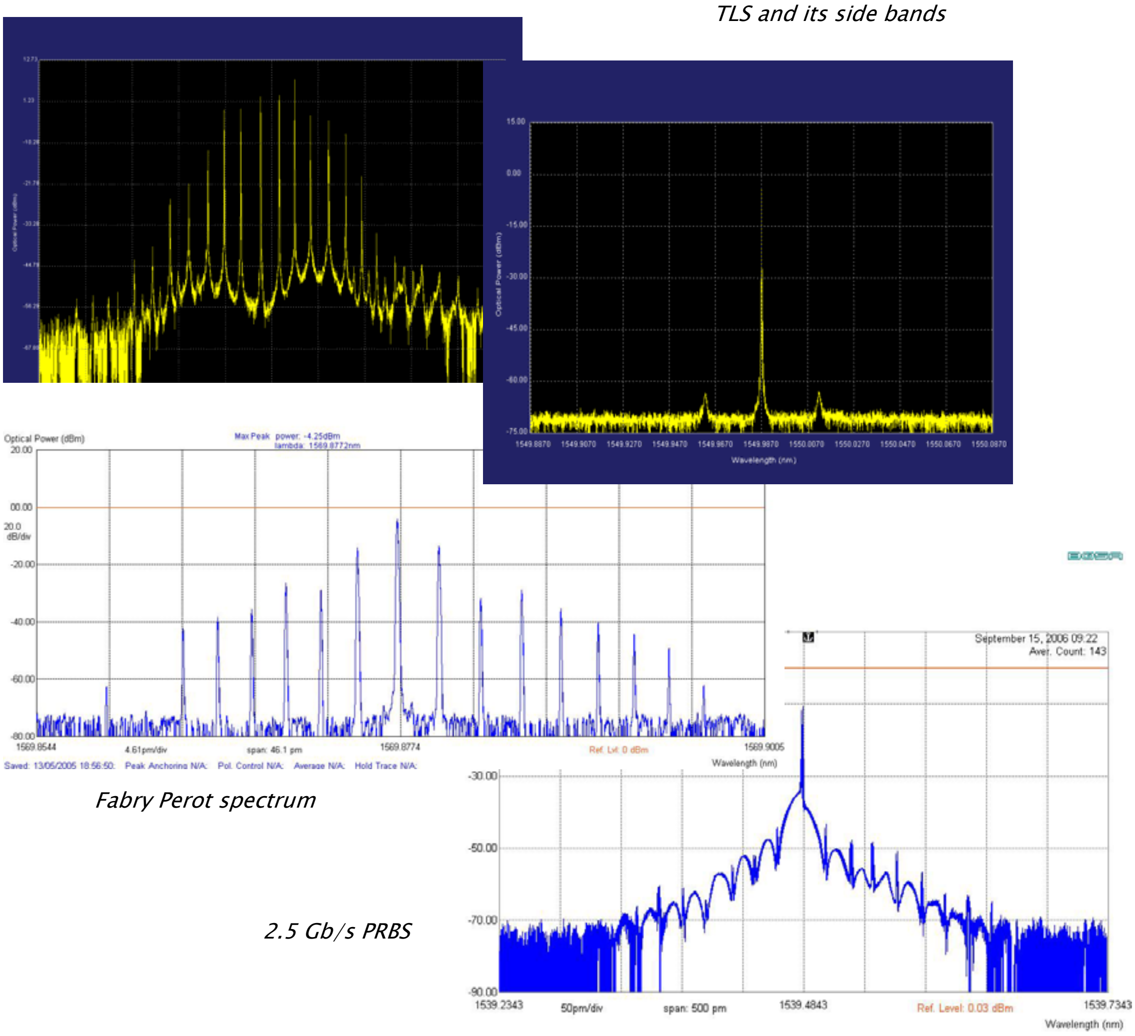
The BOSA uses the narrow Brillouin amplification window to obtain the optical spectrum of a signal with a resolution of 0.08 pm. The measurement process consists in a tunable laser (TLS) which continuously changes its wavelength along the spectral range of interest, and the simultaneous detection of the Brillouin backscattered light.



Since the TLS is changing in wavelength, different spectral components of the signal under test are backscattered and amplified. In other words, the Brillouin effect generates an active tunable optical filter of 0.08 pm width. All the filtering process takes place in the optical domain and the spectral information of the signal under test is directly reaching the detection stage. An acquisition set up synchronized with the TLS sweep stores and process the data. The TLS sweep speed can be set at high values to obtain almost real time measurements.

FWM in a SOA

TLS and its side bands



Fabry Perot spectrum

2.5 Gb/s PRBS

The interferential nature of the Brillouin interaction between measured and pump beams implies the need for a proper alignment of the polarization states of both beams in order to get the greatest efficiency in the generation of the measured signal. Specific mechanism and algorithms are internally used by the BOSA to compensate and calibrate these variations by actively controlling the polarization state of the pump beam.

The nonlinear power amplification found in the backscattered signal allows the detection of spectral components at very low power levels. Spectral components with power density of -70 dBm/0.08 pm can be detected.

The fact that SBS allows a spectral analysis strictly in the pure optical domain absolutely avoid any problem when measuring several optical signals close in frequency or using complex modulations which is a serious drawback of heterodyne methods. In addition the finesse of the optical filter provided by SBS is not achievable by the diffraction gratings technique used in conventional OSA. Moreover, the Brillouin effect does not impose any incompatibility between resolution an dynamic range, so it is possible to keep the highest values on those parameters for any measurement span.

Benefits of using SBS in optical spectrum analysis:

- Narrow Filtering: the intrinsic amplification profile of the SBS allows selection of spectral components in a width of 0.08 pm.
- Strong Amplification: the non linear behaviour of the SBS allows detection of very low power signal levels. Contributions down to -70 dBm can be perfectly measured.
- Fast: as the signal under test is strongly amplified by the Brillouin effect, small integration times are necessary in the detection chain. It allows high TLS sweep speeds reducing the time inverted in the measurements and reaching real time spectrum analysis.
- High performance: the Brillouin effect makes resolution and dynamic range perfectly compatible. Both parameters are kept at their higher values for any measurement span.
- Optical Nature: the SBS and the spectral filtering take place in the pure optical domain. Since the spectral information is directly detected there is no need of any electrical post processing. It gives several advantages against other electrical method as well as enhances the simplicity in the detection chain.

All the best
The Aragón Photonics Team
support@aragonphotonics.com