# Towards a multiwavelength passively mode-locked fiber laser.

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## 1 - Introduction

- Passively mode locked erbium-doped fiber lasers are used to generate short pulses (<100 fs) with high peak powers.
- The gain medium is homogeneously broadened and does not allow for a multiwavelength operation.
  Long cavites impose very low repetition rates (tens of MHz).
- We propose a setup to achieve passive multiwavelength operation. The spectrum of the laser is sliced by intracavity filtering using superimposed fiber Bragg gratings and specifically designed transmission filters.
- Compared to other spectrum-sliced sources, this one is simpler as it does not require high power amplifiers and propagation over long fiber spans[1].
- The intracavity filtering offers another possibility : the generation of very high repetition rate pulse bursts[2].

## 2 - Passively mode-locked soliton laser[3]

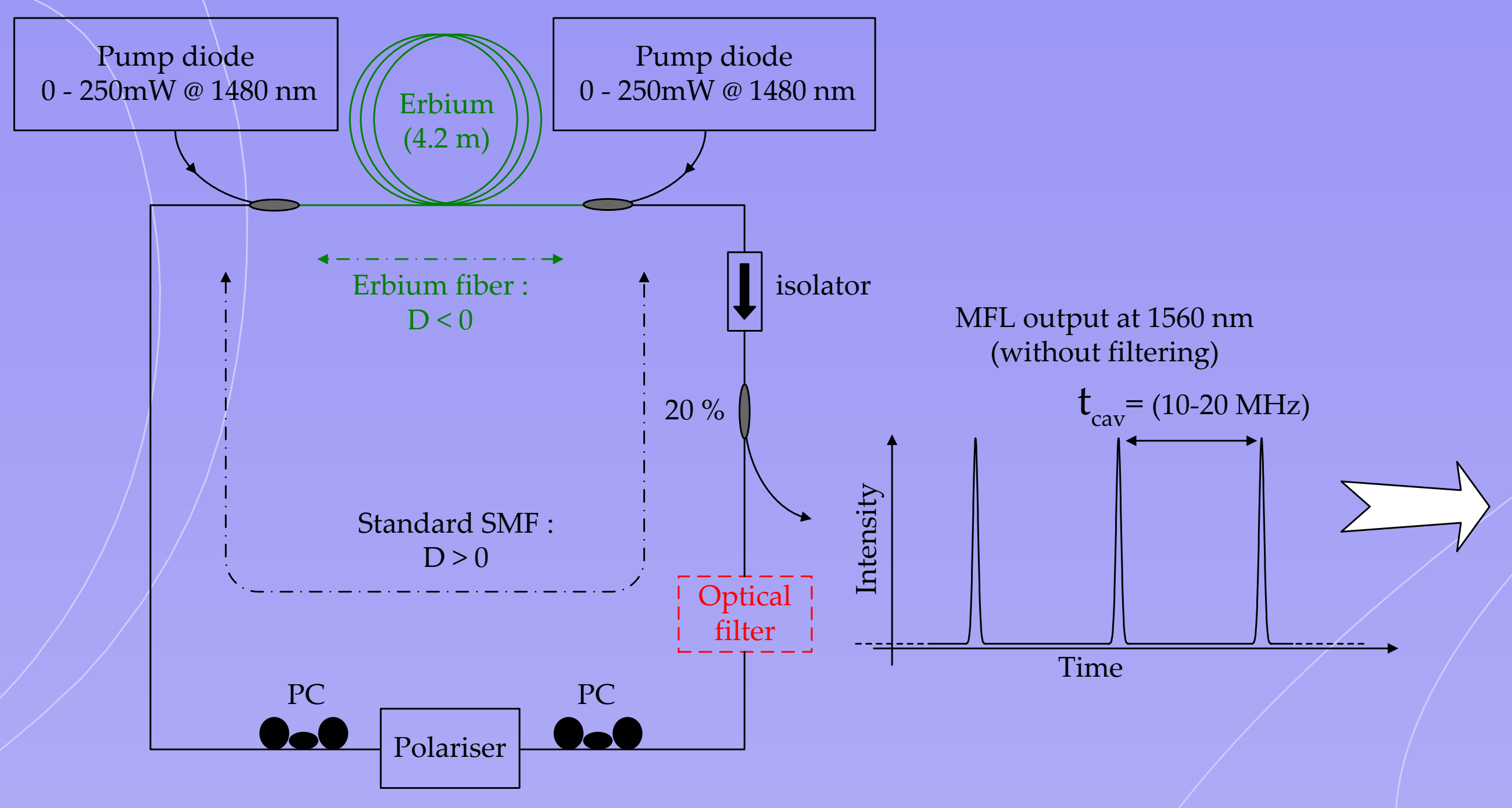

**Figure 1 :** Passively mode-locked cavity in a standard configuration[3] .

The two polarization controllers (PC) and the polarizer act a saturable absorber allowing mode locking. The purpose of the optical filter is to force multiwavelength operation (see below). The laser can generate solitons (see figures 2 and 3) with repetition rates of a few tens of MHz.

Optical spectrum
(without filtering)

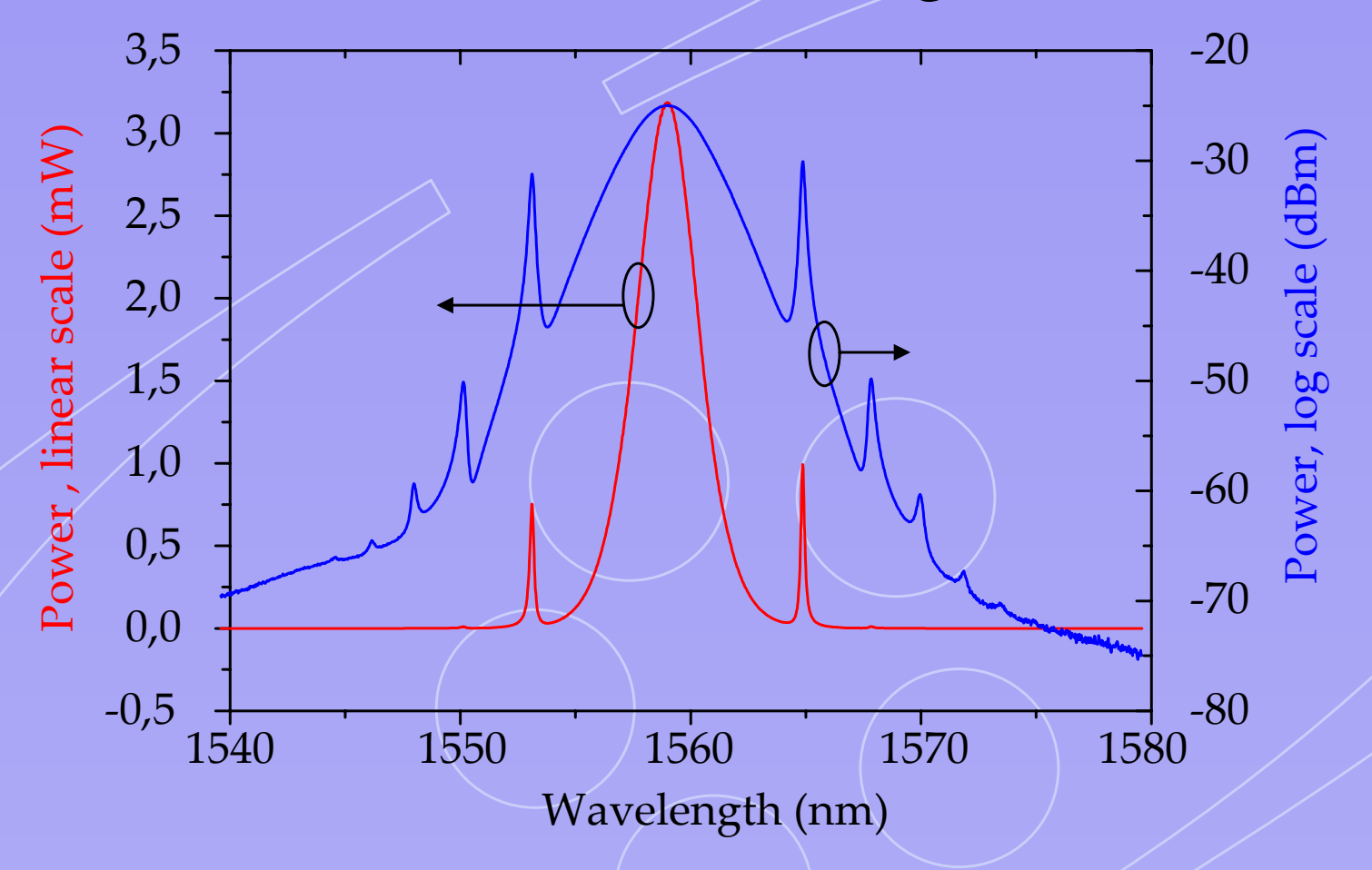

**Figure 2 :** Spectrum of the soliton laser shown in linear and log scales.

The sharp spectral sidebands[4] are a consequence of the periodical perturbation of the solitons along one cavity round trip. The spectrum is 3.1 nm wide (~400 GHz FWHM).

Autocorrelation trace
(without filtering)

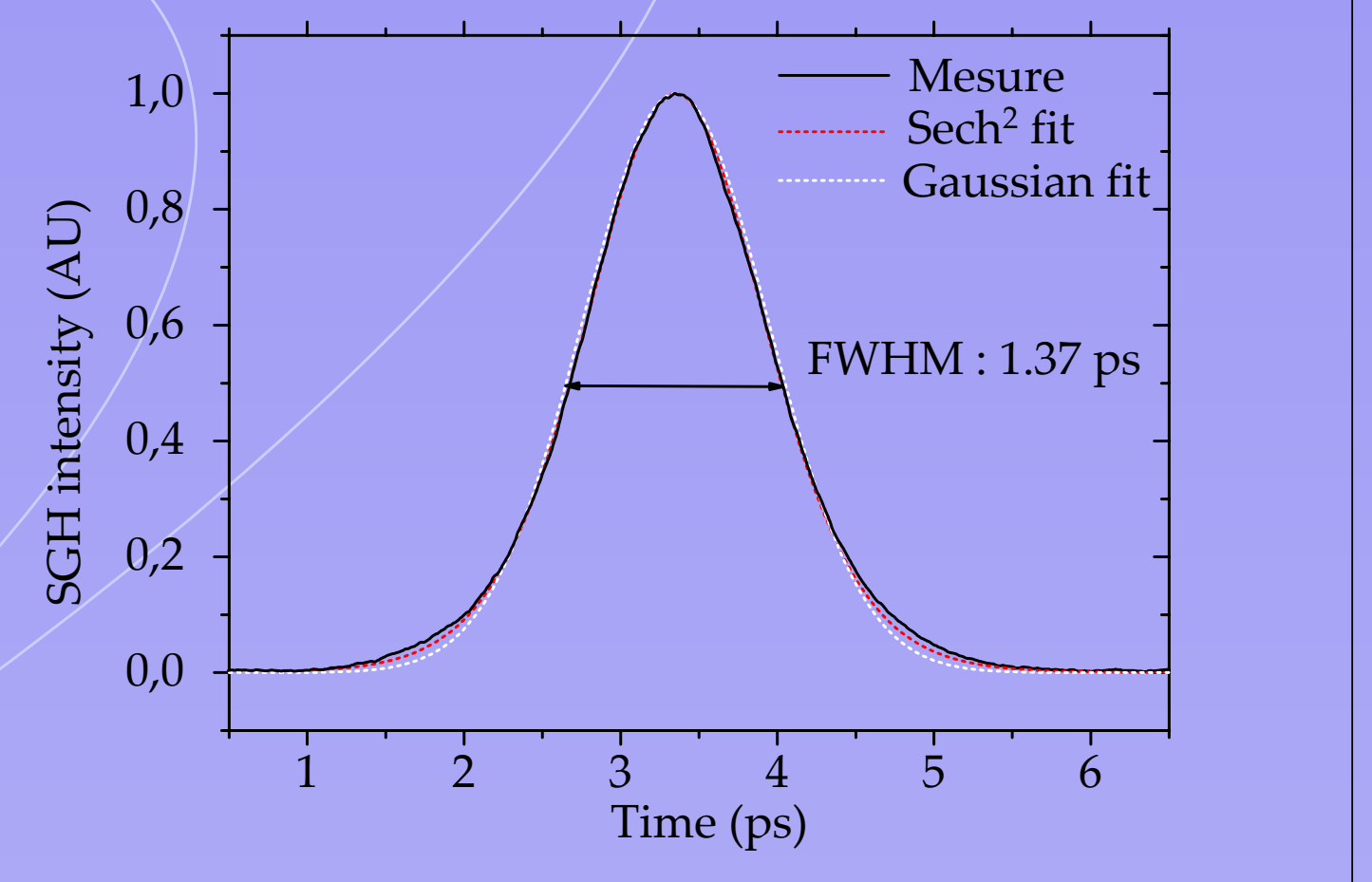

**Figure 3 :** The autocorrelation trace is closely fitted with both sech$^2$ and gaussian profiles.

The pulses have a FWHM of 900 fs if we assume a sech$^2$ profile (first order soliton). The time-bandwidth product is equal to 0.36, corresponding to nearly chirp free pulses.

## 3 - Two optical filters for multiwavelength operation

### 1. Filter based on the space-to-wavelength mapping[5] (operating in transmission)

Principle of operation

Linearly chirped fiber Bragg grating:
fiber : Ge doped - H2 loaded.
phase mask : 140 mm long
chirp = 2.58 nm/cm.

Single pass apodisation :
resolution = 0.2 mm
total length = 140 mm
eight supergaussian structures

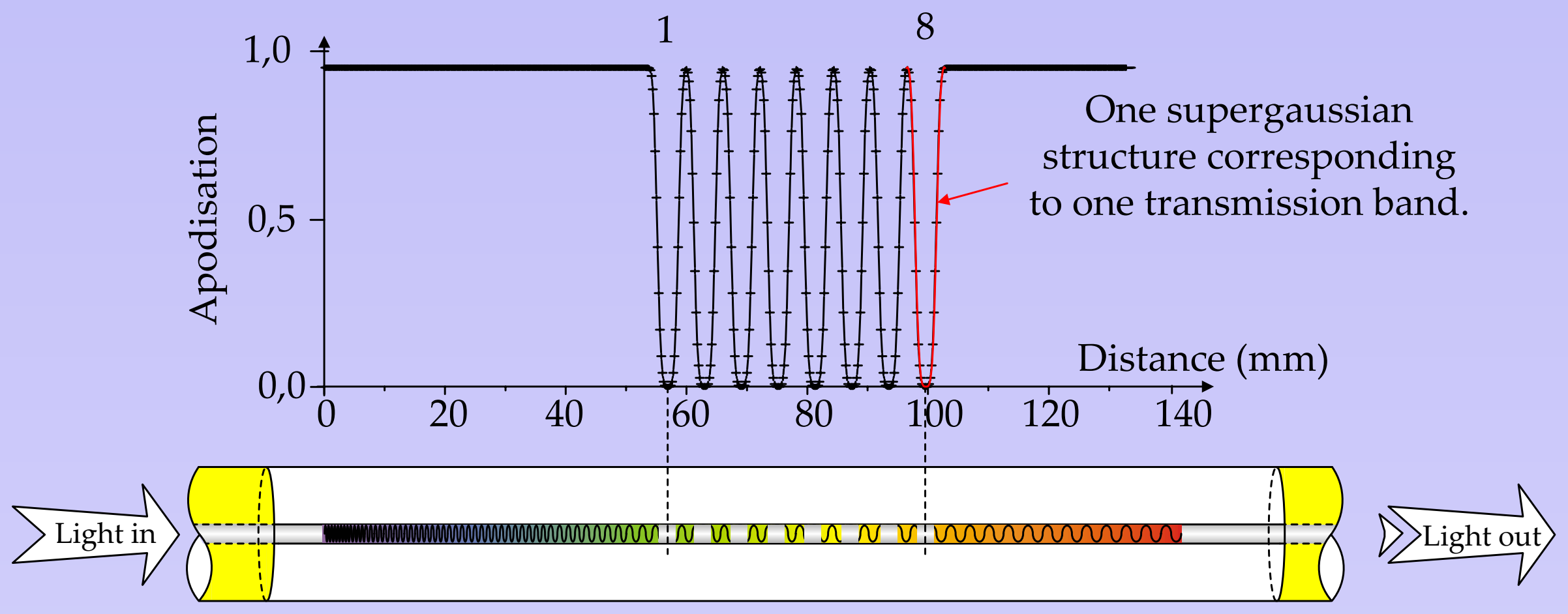

**Figure 4** : An optimized apodisation profile (top) is used to fabricate an eight wavelengths filter.

Instead of being reflected, the eight selected spectral-bands will be transmitted as they do not see an index modulation.

An eight wavelengths filter

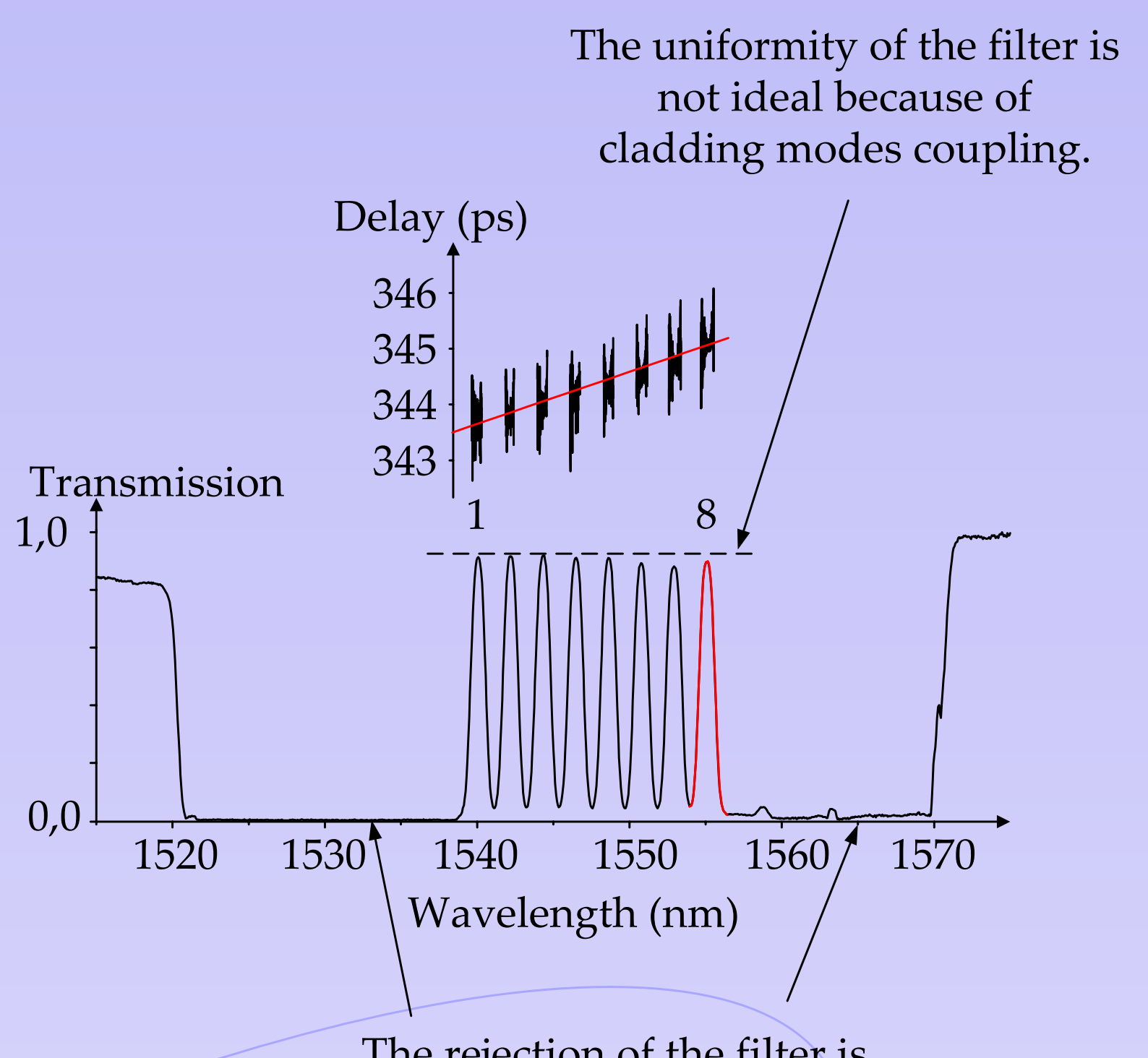

**Figure 5** : Spectral response of an 8 wavelengths filter.

The apodisation profile shown figure 4 was used to fabricate this filter. As expected, the phase is not affected by the filtering.

3 mode-locked wavelengths
with a 4 wavelength filter

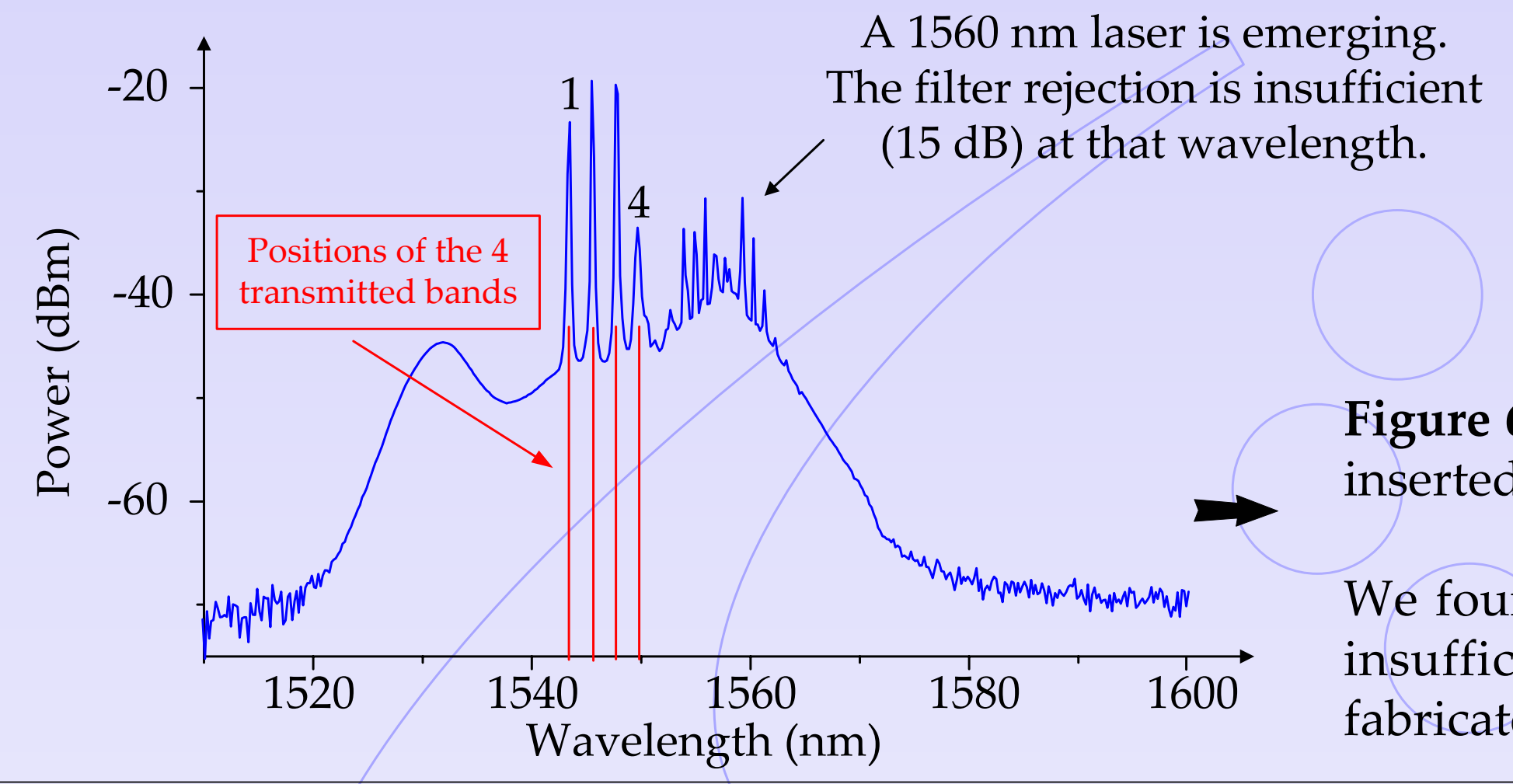

**Figure 6** : Laser spectrum when a 4 wavelength filter is inserted in the cavity.

We found that the rejection of the filter at 1560 nm is insufficient. New filters with higher rejection will be fabricated before doing any further investigations.

### 2. Superimposed fiber Bragg gratings : (operating in reflection with an optical circulator)

Reflection and delay spectra of the 8 superimposed FBGs :

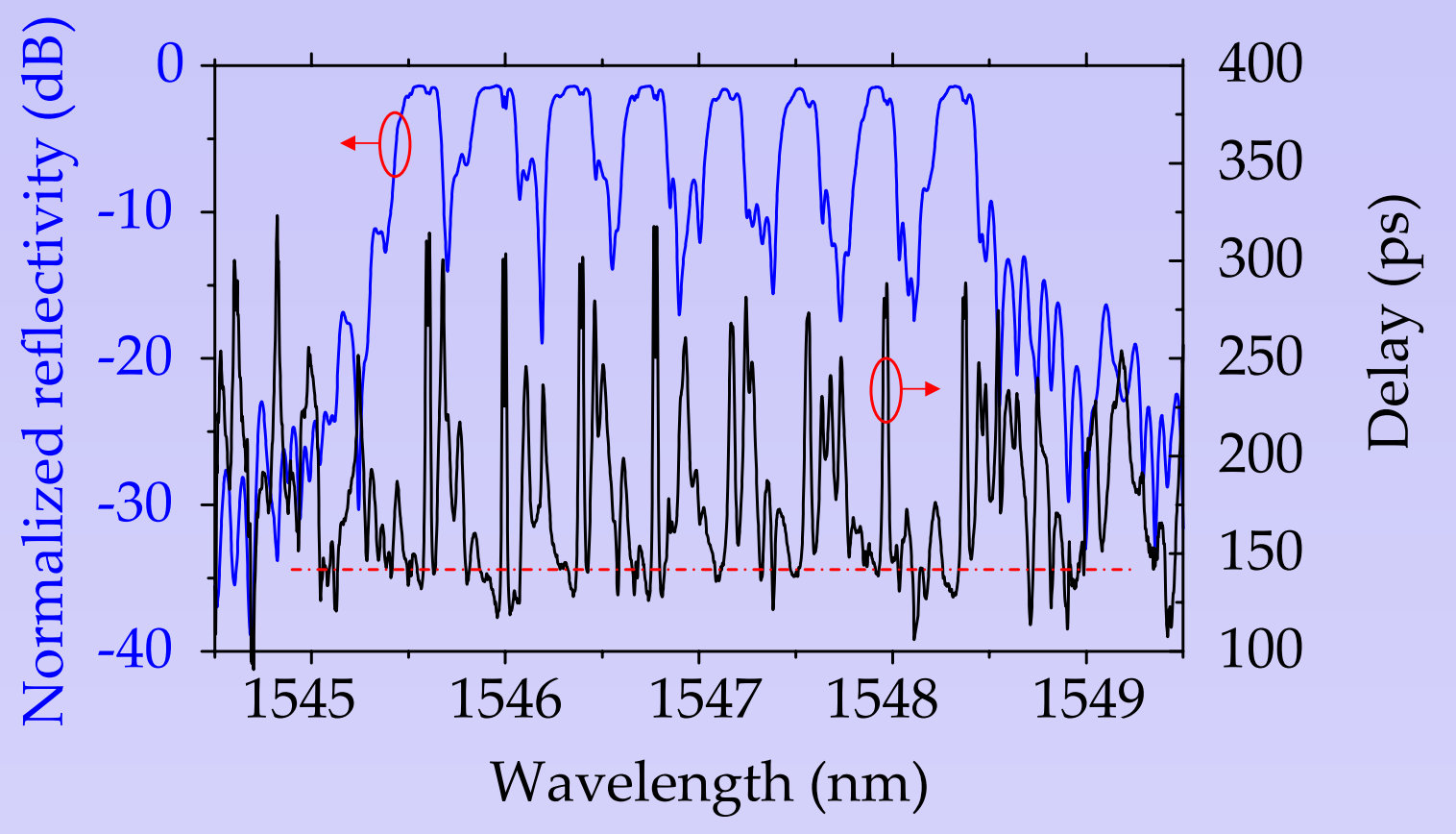

**Figure 7** : Spectral response of 8 superimposed fiber Bragg gratings.

The delay response is not very uniform which impedes the synchronisation of the wavelengths.

Laser optical spectra

Second harmonic
autocorrelation traces

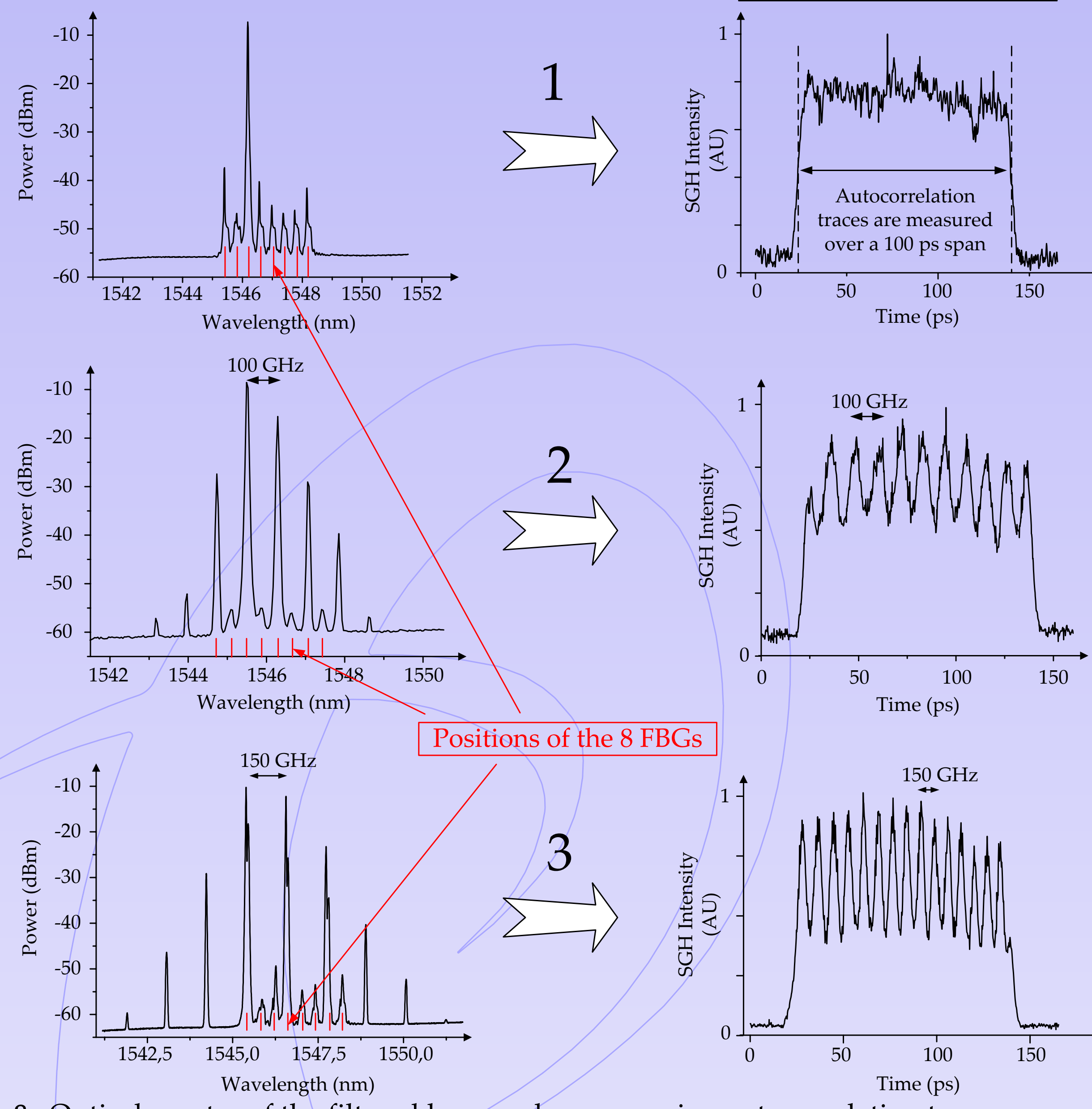

**Figure 8** : Optical spectra of the filtered laser and corresponing autocorrelation traces.

We observed a periodic selection in the spectrum which is not understood yet. The autocorrelation traces correspond to a long pulse (1) and pulse bursts (2 and 3) of the same length. In the last two cases, we could vary the spectral peak spacing simply by adjusting the polarization in the cavity. The pulse bursts had repetition rates that matched the spectral spacing.

## 4 - Conclusions

Laser

- Multiwavelength mode-locked regime was obtained in an all-passive way by intracavity spectral slicing.
- In order to increase the number of wavelengths, we will have to shorten the pulses i.e. widen the spectrum of the laser (see figures 3 and 4). This can be done by controlling the dispersion of the cavity[3].
- The different wavelengths are in phase and beat to produce pulse bursts at very high frequencies.

Filtering

- Transmission filters were designed and realized. The next step is to increase the rejection of the filter and keep the cladding modes as weak as possible.
- Superimposed fiber Bragg gratings, with narrower bandwidths and closer spacings, offer an alternative to transmission filters. Moreover, they have a high rejection at 1560 nm.
- With superimposed FBGs, we observed an interesting feature in which the mode locked laser «selects» a periodic spectral pattern. With the current setup we were able to generate pulse bursts at frequencies up to 350 GHz.

## References

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