Raman amplification is well-known to offer the advantages to provide flat gain and wideband amplification in conventional low-loss silica fibers itself, at any wavelength for which a pump with frequency higher than that of signal by the Stokes shift is available and to permit distributed amplification allowing smaller magnitude excursion of the signal level and therefore low non-linearity impairments and lower noise than lumped amplifiers.

Noise figure analysis is therefore one of the key topics in Raman Fiber Amplifier (RFA) design and analysis and it is determined by four major sources for noise.

Because of the amplification of two non commutating quadratures of the optical field, RFA are subject to intrinsic quantum noise generation leading, for instance, to the 3 dB noise figure minimum in the high gain limit. We will first consider this corresponding noise generation, usually described in terms of Amplified Spontaneous Emission (ASE), and show that it is produced by the vacuum fluctuation input noise amplification and of the intrinsic amplification and attenuation noises mechanisms. Because of the very fast relaxation of the optical phonon, the lower state is nearly empty, the virtual inversion population is almost complete, keeping the quantum noise very close to its minimum value. As stimulated Raman scattering is nearly independent of the pump and signal propagation direction, fiber Raman amplifiers can work both for the counter propagating and co propagating pump with respect to the signal. Since a large gain is first experimented, the latter is preferable, as far as only intrinsic noise is concerned.

The second noise impairment to be discussed results from the small Raman absorption cross-section requiring high power pumps exhibiting a large noise, usually described in terms of Relative Intensity Noise (RIN). Since Raman amplification operates through virtual excited states, no population inversion smoothes out the pumps fluctuations, and an instantaneous value of the signal experiments a fluctuating value of the gain resulting of gain averaged over the pump to signal walk off time. Counter propagating configuration is therefore more
favorable at high modulation frequency for RIN transfer from the pump to the signal. We proposed a novel frequency model to evaluate the pump to signal RIN transfer in multi pump amplification of WDM signals. The model takes into account the pump depletion and pump-to-pump, pump-to-signal and signal-to-signal interaction.

We will finally pointed out that the pump State of Polarization (SOP) temporal fluctuations in the presence of PMD influence the amplified signal noise and propose an analytical expression of the transfer function.

Performance of RFA as usually compared to lumped Erbium Doped Fiber Amplifier (EDFA). The better noise performance of the former are usually is represented by the so-called effective noise figure. This concept may be misleading, since thank to the distributed amplification the effective noise figure could be negative. We discuss in detail relation between standard and effective noise figure definitions.