Summary

In this thesis the application of machine learning (ML) and artificial neural networks (ANNs) to optical communication systems is investigated in the context of multi–band systems (O–, E–, S–, C– and L–bands). Indeed, systems operating beyond the commercial C–band (~ 5 THz) are envisioned in future optical networks to sustain the ever increasing capacity demand due to the exponential growth of Internet traffic. Consequently, upgrades and new technological advances need to be introduced in the already deployed telecommunication infrastructures to handle multi–band transmissions.

At the same time, the already existing analytical models for system performance assessment should take into account those fiber impairments that were negligible in the limited C–band which, however, become important when extending the transmission bandwidth. Among these, inter–channel stimulated Raman scattering (ISRS), responsible of a power transfer from higher to lower frequency carriers that also depends on the spectral load at the input of the fiber, may significantly affect the performance of real–time flexible multi–band systems subjected to dynamic change of data traffic.

For this reason, it is fundamental to accurately determine the impact of these effects in a fast way for a quick and suitable system response. Nevertheless, standard approaches based on analytical closed–form models and numerical solvers face an increase of computational time and complexity that follows the extension of bandwidth. Here, we propose the use of ANNs in substitution of numerical solvers and in support of analytical models in the evaluation of power profiles evolution along optical fibers, especially including ISRS. The analysis is carried out for thousands of different input spectral loads and different fiber span lengths.

Together with the extension of transmission bandwidth, new amplification technologies are required, as the currently most deployed erbium doped fiber amplifiers (EDFAs) only operate in the C–band with an extension to the L–band. Among possible solutions, Raman amplifiers (RAs) represent an interesting cost-effective option because, by exploiting the stimulated Raman scattering (SRS) effect present in any fiber, they can provide amplification gain potentially over all optical bands without the need of installing new fibers. Furthermore, with RAs it is possible to obtain gain profiles of any shape by simply tuning the Raman pump lasers in

number, wavelength (frequency) and power, solving an inverse design problem.

Based on its great potential in solving complex problems reducing their computational complexity, in this thesis ML is also applied to RAs. Precisely, we present two ANN types: the *direct* ANN used to evaluate gain and ASE noise profiles of RAs, and the *inverse* ANN to design RAs for desired gain profiles. The two ANN models are proposed as possible alternatives to standard approaches based on the numerical solution of sets of nonlinear differential equations describing the Raman effect, which indeed become highly computational demanding in case of multi–band transmission as the complexity scales with the number of equations to solve. The high prediction ability of the two ANN models is investigated for a broad range of scenarios over both synthetic and experimental data, spanning from *full* to *partial* spectral loads, analyzing different fiber types and considering different transmission bandwidths (C–, C+L– and S+C+L–band).