The fundamental concept of optical fibres has not been changed for the last 60 years due to constrains of the standard optical fibre development technology. Presently, improvements to fibre-based devices are made through adaptation of the peripheral devices, as means of working around the limits of optical fibres. Limitations of the traditional fibre design limits the flexibility in shaping their optical properties as modal, dispersion, polarization properties, confinement and bending losses and limited power transfer. Nowadays, these limitations need to be compensated by additional dedicated external components.

Previous studies of the leading telecommunications companies anticipated the year 2015 as the limit of the single mode fibre (SMF) transmission capabilities. In 2013 and 2015, the highest possible bandwidth was achieved in single-mode fibre using DWDM multiplexing of 60Tbit/s and 100Tbit/s, respectively. New multicore fibres MCF (Multicore Fibres) and FMF (Few Mode Fibres) have been under the development for nearly 10 years to show new routes to increase bandwidth. In 2018, Sumitomo performed an experiment showing transmission in a 19-core optical fibre with spatial multiplexing on 3 modes and with DWDM wavelength multiplexing, during which a bit rate in a single fibre of more than 10Pbps was achieved. This is nearly 100 times the capacity of the single-mode fibre. The current publications put the hypothetical future transmission capacity of such fibres expressed as a function of bit rate and length at 1 Eb/s (exa bit/s). Current MCF and FMF outperforms SMFs, but their development face limits related to Modified Chemical Vapour Deposition MCVD technology, used as a standard fabrication approach. The limits are related to rotational symmetry of refractive index distribution and limited doping level.

In this project we propose a radically new approach based on nanotechnology for free-form fibre development. In this case the fibre core is composed of thousands of nanorods of various glasses which form an effective refractive index distribution in the fibres, according to nanorods distribution. This way an arbitrary effective distribution of the refractive index in the core is obtained without any angular symmetry limits as existing in standard fibre preform fabrication technologies.

The free-form fibres significantly differ in their concept and technology from the classical MCVD based fibres, as well as the photonic crystal fibres, and can be treated as a separate class of optical fibres. The nanostructured free-form fibres are all-solid (no air holes in the fibres), have standard dimensions and can be implemented with up-to-date tools and by standard skilled personnel These fibres are fully compatible with the current silica glass based telecom systems and can be matched with the existing telecom networks. The ground-breaking advantage which underpins this concept, is the feasibility of engineering of effective fibre parameters owing to the nanostructuring approach. Flexibility in the engineering of optical properties (chromatic dispersion, modal, polarization) outperforms those offered by the standard MCVD technology. With this approach we take advantage of the constant progress in MCVD development of enhanced, low loss materials, since we use doped silica rods developed with this technology.

In this project we plan to develop new algorithms based on artificial intelligence to design free-form fibres and explore their flexibility in shaping of optical properties of the fibres. Up to know, we have used simulated annealing algorithms to determine internal structure of the fibre composed of the nanorods and mimicking the arbitrary designed continuous refractive index profile. This method allows for very accurately obtaining any dedicated effective refractive index distribution, but it does not provide the possibility to design the effective parameters of the fibres. To address this shortcoming, we will work out and implement new fibre nanostructure design algorithms involving deep learning, which shall be returning the effective refractive index distribution in the core, based on predefined optical parameters of the fibre introduced as input parameters. Next, we plan to develop and experimentally verify the advantage of free-form fibres for development new types of few mode fibres (FMF), large mode area (LMA), multiple core fibres (MCF) (single mode and few mode cores) dedicated to high bandwidth short- (data centres), long-distance (access network & long-haul) fibre lines and fibres with enhanced Rayleigh scattering (ERS fibres) and outperform existing solutions. Finally we will build at least 3 demonstrators of new fibres to benchmark with existing fibres and verify their performance in the test telecom lines.