Wroclaw Quantum Network – QKD deployment in a metropolitan network

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The optical infrastructure is determined by the city telecommunication cabling layout. Dark fibers connecting two, even not very distant metropolitan locations physically sharing an industry-standard telecom fiber with many parallel fibers (constituting the Krystaal POF topology and medium for QKD network) are divided in a series of thermally welded interconnections and junctions at telecom cabling crossings, which are the main reason for decoherence and quantum signal losses, resulting with increased QBER and with inflexibility of key distribution in practical scenarios (this is specifically addressed to dark fiber infrastructure of metropolitan backbone telecom networks with multiple interconnections of telecommunication optical lines, which are implemented by thermal weldings – a connection between two locations separated by ca. 5-6 km distance, is usually divided by over several fiber weldings).

Due to significant investments in Wrocław University of Technology laboratory equipment encompassing current state-of-the-art quantum cryptography technologies within the Postos National Quantum Technologies Laboratory programme, as well as technological partnerships with internationally leading vendors of quantum cryptographic systems and national information security institutes and companies, city of Wrocław now hosts a unique metropolitan quantum research and development project.

Research on QKD deployment in practical telecommunication networks environment resulted in evaluation of boundary conditions for QKD system key versus quantum channel and transmission parameters and a successful resolution of channel key by protocol proper alignment of experimental setups. The fiber optics line of the SMF-28 standard has been used to test different connections and welding configurations for two R&D QKD apparatuses based on the DQK-scheme Claves, low (non-entanglement) QKD, enabling plugging in interfering phase shifts of laser impulsions (in Michelson interferometers) and the Antiga Qutek setup (entanglement QKD), encoding pairs of polarizations of entangled photon pairs generated in non-linear PPKPV crystal, in a SBS crystal). The main optics fiber line (single mode SMF-28 standard) has been subsequently modified in laboratory tests by welded or interconnected DQKNAAC and QFCPC adapters. The interconnections resulted with high QBER increases, thus focusing thermal welding which in proper proximity distribution were characterized by ca. 10 times lower loss induction than interconnectors (ca. 0.01 dB per welding, depending on the polymers). Next the industry standard telecom fiber optics line tests have been carried out towards welding and interconnections configuration optimizing in regard to QBER and conditioning of the metropolitan network deployment. Primary focus was directed towards the non-entanglement based setup which turned out to be operating properly with an acceptable raw key exchange rate (RKE) generating targeted amount of displaced secret bits (DSB) under laboratory simulation of real optical fiber backbones metropolitan network configuration with required optimization of interconnections and welding infrastructure. The entanglement-based QKD has been tested for the first time in a real telecom network environment and proved to be also feasible but within a very narrow gap of optical elements alignment and poor (asparatic) values of QBERs and RKEs with high additional instability of operation parameters. This research allowed for the current deployment of the QKD metropolitan network in Wrocław.

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Measurements were performed for different number of fiber interconnections, different fiber types and different welding techniques. In the experiments a 7 km fiber span SMF-28 with 750/2000/7000 round loop were used (ca. 4.5 km and up to be weldings (thermal optical fiber weldings), 2 meter SMF-28 fiber segments with FC/PC connectors (interconnected via FC/PCC ferrules adapted).

Experimental and even early commercial QKD implementations are very susceptible to technical conditions of the transmitting media (i.e. optical fiber infrastructure and associated alignment of the quantum optics) therefore deployment of QKD systems in real metropolitan optical fiber infrastructure network poses a challenge.

![Image of experimental setup](image-url)