Optical fuse as a countermeasure against light injection attacks on quantum key distribution systems

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Abstract— In this paper, we propose an original device that can protect QKD systems from the effects of intense laser radiation. Carbon nanomaterials dispersed in a polymer can be used as a fuse for quantum key distribution (QKD) systems.

Keywords— fuse, protection of quantum key distribution systems (QKD), protection against light injection attacks

I. INTRODUCTION

QKD systems have a number of vulnerabilities related to the imperfection of real hardware. In particular, it is possible to carry out attacks by injecting Eve's laser emission into QKD. There are the following types of attacks: the Trojan-horse attacks, the laser-seeding Attack, the laser-damage attack, etc.

Here we propose carboxymethyl cellulose films with dispersed single-walled carbon nanotubes (CMC-CNT) [1] as a fuse for QKD systems, preventing attacks by high-intensity laser emission on Alice. This element under thermal influence fundamentally changes its characteristics.

The samples were tested under the influence of a 1550-nm CW high-power laser, and their behavior in QKD systems was demonstrated.

II. EXPERIMENT

The samples under tests are home-made CMC-CNT films with thickness of about 5μm and initial attenuation at 1550 nm of about 3.5 dB. They were placed and fixed between fiber-optic connectors. To simulate Eve's attacks, we expose them using a 1550-nm CW laser with maximum power of 6 W and record the power transmitted thought the samples. Each sample is exposed to the constant power level for 5 minutes, afterward, films are studied using optical microscopy and Raman spectroscopy. Moreover, samples were tested in two QKD systems based on BB84 protocol with phase and polarization encoding produced by QRate. QBER and the length of the generated key were evaluated both with and without the inclusion of the proposed element.

III. RESULTS AND DISCUSSION

Increase in attenuation occurs under exposure to power of more than 5 mW. However, an irreversible increase in attenuation by 5 dB and more observed when exposed power is more than 170 mW. At a power from 1 to 2 W, the fiber fuse effect occurred. The presence of CMC-CNT at the junction of two fiber optic connectors reduces the threshold for the appearance of an optical spark in comparison with pure connectors. Therefore, tested samples protect a system using two mechanisms: an increase in attenuation and optical spark effect. Increase in attenuation prevents damage to other components in the system. Catastrophic damage to the optical fiber interrupts key generation, and that way protects a system against third-party intervention. To avoid damage to a large section of the quantum channel by optical spark , an adiabatic tapered fiber (cone-shaped narrowing), which stops the fiber fuse, might be placed after the fuse. The analysis of damage under the microscope and Raman spectroscopy (Fig.1) shows a complete degradation of the sample structure. Raman spectra shows that CNT transforms into an amorphous phase. Also, the scattering background in the polymer was somewhat higher, since after melting the surface of CMC-CNT ceased to be smooth.

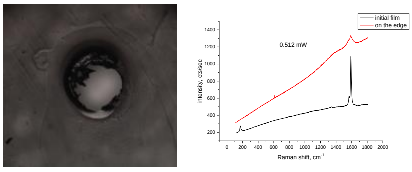

Fig. 1. A) 10-fold increase in sample damage B) Raman spectrum of the sample after exposure with a power of 512 mW

Theoretically, the inclusion of materials such as CMC-CNT should not affect the operation of systems with either polarization coding or phase shift coding. This hypothesis has been tested in practice.

Thus, it can be concluded that samples with CMC-CNT do not affect the normal operation of the system

CONCLUSION

A fuse device is proposed, including CMC-CNT and an adiabatic taper. The taper is designed to stop an optical spark and prevent damage to the line.The CMC-CNT was installed in various QKD systems: the main indicators of the system remained at the same level.

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REFERENCES

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