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Letter of recommendation for Jan Soubusta, assoc. prof., Mgr., Ph.D.

I am glad to strongly recommend Jan Soubusta, assoc. prof., Mgr., Ph.D., to you in his application for the title of *Professor of Science* for his scientific achievements. I hope this letter in support of this Candidate could be useful in this evaluation.

The Candidate defended his Ph.D. thesis on "Study of the optical properties of double quantum wells in electric and magnetic fields" under the supervision of assoc. prof. Milan Zvára at the Faculty of Mathematics and Physics of Charles University in Prague in 2000. And in 2010, he defended his habilitation thesis on "Using spontaneous parametric down-conversion in optical experiments" at the Faculty of Science of the Palacký University in Olomouc.

The Candidate had been employed at the Institute of Physics of the Czech Academy of Sciences in Prague in the years 1995–1997, and at the Institute of Physics of the Charles University in Prague in the years 1995–1999. He has been working at the Joint Laboratory of Optics of Palacký University in Olomouc since 1998.

Within his carrier, the Candidate has been performing fundamental and applied research in several branches of physics with a special focus on quantum optics and quantum information. Both research fields are closely related to quantum technologies. Specifically, his research covers quantum cryptography, quantum communications, quantum random number generation, and quantum information theory including quantum entanglement and other types of quantum correlations. His scientific activities also include: optoelectronics, as well as classical linear and nonlinear optics for testing optical properties of nanomaterials and interferometry.

In general, the Candidate has elaborated various theoretical proposals as a challenge to solve some important problems in quantum technologies and has build experimental setups and devices to support the proposed theories. He also worked on theoretical descriptions of experiments, but more often collaborated with theoretical physicists in his areas of interests.

I would like to mention a few technical points that might help you to be acquainted with the areas, in which the Candidate contributions could be recognized by awarding him the scientific title of professor.

The Candidate has started his scientific carrier in optoelectronics by measuring optical spectra of the luminescence of quantum wells. During his Ph.D. studies he developed several methods for tuning the interaction of particles in double quantum wells using an electric field. These effects predicted theoretically were confirmed experimentally and his results published in Physical Review B [**60**, 7740 (1999)] are still highly valuable. He has continued this research topic recently with his

students by constructing a microscope apparatus for measuring micro-photoluminescence spectra of different nanoparticles.

He has actively participated in several quantum cryptographic projects conducted in Olomouc. He personally designed and assembled a prototype of an optical quantum random-number generator. This generator is based on a fundamentally random process of light splitting on a beam-splitter and, thus, the generated random data pass all the randomness tests. He also participated in the improvement of the apparatus for scanning 3D surfaces of tested objects using white-light interferometry as reported in his article published in Applied Optics [**43**, 766 (2004)].

He was one of the pioneers in Olomouc of using the process of spontaneous parametric down-conversion (SPDC) for generating correlated photon pairs in nonlinear crystals pumped by continuous-operating laser. He was testing temporal and energy correlations within correlated photon pairs. Using single-mode fibers he experimentally achieved the interference visibility above 98% in these experiments [Phys. Lett. A **319**, 251 (2003)]. He was a leading experimentalist designing different optical setups for quantum cloning of single-photon quantum bits (qubits). He has thoroughly studied several universal and phase-covariant cloning experimental machines [Phys. Rev. A **76**, 042318 (2007) and Phys. Rev. A **78**, 052323 (2008)]. He was leading an experimental team, which was using SPDC generated photon pairs as an input for different quantum gates including: multimeters, discriminators of unknown states, SWAP gate, symmetrization and anti-symmetrization gates [Phys. Rev. Lett. **100**, 180501 (2008)]. He was also a leading person connecting the theoretical study of photon pairs generated in periodically-poled KTP waveguides in experiments performed in Olomouc. His theoretical calculations fit very well the measured spectra and they allowed to assign individual spectral components of the interacting fields with their spatial distribution modes [Phys. Rev. A **87**, 013836 (2013)]. Together with his colleagues demonstrated, to my knowledge, the first in the world fully functional linear-optical controlled-phase gate performing a controlled phase shift [Phys. Rev. Lett. **106**, 013602 (2011)]. This kind of a gate is a universal building block for many quantum information protocols. Later on, he concentrated on designing several basic elements for optical quantum information networks, namely quantum routers and quantum amplifiers. He used his experience at the boundary of classical and quantum optics for testing limits in processes of transferring information between different quantum information carriers. Moreover, he was testing various conservation laws, which apply during unitary transformations between the degrees of coherence and correlations of individual parts of a quantum system [Phys. Rev. A **97**, 042305 (2018)]. Recently, together with his experimental group, he succeeded to build an optical setup for fast generation of generalized Greenberger-Horn-Zeilinger (gGHZ) states. With this setup they were able to test Bell-type inequalities violation for these maximally entangled three-qubit states [Phys. Rev. A 99, 042123 (2019)]. For testing the degree of entanglement of these states, he used a newly defined quantity called a nonlocal fraction [Phys. Rev. A **101**, 052109 (2020)].

I find these and other works of the Candidate very insightful and useful for quantum technologies.

According to the Web of Science, the Candidate coauthored 52 publications, which were cited 765 times as checked on August 18th, 2022. His H-index is 18. His three most often cited papers according to the Web of Science, are: (i) the article on ,,Resource-efficient linear-optical quantum router" (coauthored by K. Lemr, K. Bartkiewicz, and A. Černoch) published in Physical Review A in 2013 and cited 55 times; (ii) the article on ,,Measurement of the influence of dispersion on white-light interferometry"(coauthored by P. Pavlíček) published in Applied Optics in 2004 and cited 53 times; and (iii) the article on ,,Experimental Implementation of the Optimal Linear-Optical Controlled Phase Gate" (coauthored by K. Lemr, A. Černoch, K. Kieling, J. Eisert, and M. Dušek) published in Physical Review Letters in 2011 and cited 52 times.

The Candidate is able to: (i) collaborate with theoreticians from different areas of physics, (ii) propose original solutions to experiments, (iii) carry out these experiments, and (iv) find connections

to theoretical predictions. Colleagues and students praise his ability to connect people and ideas and find appropriate solutions. The Candidate is also capable to motivate them to do a meticulous work necessary to obtain precise results. He uses his personal experience also for teaching and successfully supervising students. He has been teaching for nearly two decades several basic courses in physics, and also several specialized subjects and laboratory practices.

At the end of this part summarising some scientific achievements of the Candidate, let me note that I have been collaborating with the Candidate for more than ten years and, as a consequence, I am well aware of his research activities. I find this collaboration very fruitful, efficient, and enjoyable. In particular, our paper (coauthored by K. Bartkiewicz, K. Lemr, and A. Černoch) on „Experimental eavesdropping based on optimal quantum cloning", which was published in Physical Review Letters in 2013, has attracted much interest of a general public. It was advertised in the article on (1) "Quantum codes open to attack of the clones" by Jacob Aron published in New Scientist (2013-05-3), which was reprinted at dcsoft.info (under the title "Quantum clones let hackers censor in credentials noise"), ElectronicsWeekly.com, and German Security News (at twitter.com). Moreover, it was described in the articles on: (2) "Quantum Cryptography Not So Secure After All" posted at techngaming.com (2013-05-5), (3) "Quantum Cloning: la crittografia quantistica non e' a prova di hacker" (in Italian) in Cyberscienza (2013-05-6); (4) "Eavesdropping quanta" (in Polish) by Mariusz Błoński at kopalniawiedzy.pl (2013-05-06) and reprinted at a number of websites; (5) "Quantum hackers can hide in the background noise" (in Korean) in the KISTI preview "Global Trends Briefing" (2013-05-09); (6) "Attack of clones: Quantum eavesdropping of banks" (in Polish) by Ludwika Tomala published at PAP–Science in Poland (2013-05-10); (7) "Quantum cloning in RCPTM threatens secure communications", featured results of the RCPTM; (8) "Citlivá data budou díky olomouckým vědcům ve větším bezpečí by Martina Šaradínová in Žurnal UP Online (2013-05-24); (9) "Citlivá data budou díky olomouckým vědcům více v bezpečí" by Vlasta Hradilová in Novinky.cz (2013-05-24); or (10) "Jak ochránit citlivá data" posted at Gate2Biotech.cz (2013-05-28).

Through our collaboration and in my knowledge of quantum nonlinear optics and quantum information, I find him an excellent researcher with already significant contributions to these fields. The Candidate can easily grasp the nature of a physical problem, put forward creative proposals, and solve the problem efficiently and quickly. He has also a very creative scientific way of thinking. The last but not least, the Candidate is a kind, modest, highly honest, and loyal person.

Thus, I am glad to strongly recommend the Candidate, as a high-rank expert in the fields of theoretical and experimental optoelectronics, quantum optics, and quantum technologies. I deeply believe that he fully deserves the title of *Professor of Science* for his scientific achievements.

If further information is required, please feel free to contact me. I now stand ready to render all my possible support for the Candidate.

Yours sincerely,

Adam Miranowicz