THE AUSTRALIAN NATIONAL UNIVERSITY

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Re: Report on the Habilitation Thesis "Fast-switching photonic crystal fibers infiltrated with ferroelectric and nematic liquid crystals" by Dr. D. Budaszewski.

Dear Habilitation Committee

Dr Budaszewski's Thesis is based on a set of eight publications denoted as H1,...H8. These articles were published in recognised technical journals including Optics Letters, Optics Express, Liquid Crystals, and others, during the period 2014-2023. They form a relatively coherent set dealing with optical properties of liquid crystal infiltrated photonic crystal fibers. The subject of optical applications of liquid crystals belongs to one of the topics intensively investigated in many internationally recognised research groups. This interest is driven by real and potential applications of liquid crystal systems in optical sensing, displays, and, generally, optical signal control and processing. This is confirmed by a vast number of scientific papers published annually and many international conferences devoted to this subject. Therefore, the contents of the enclosed articles clearly fit into this active area of research.

In general, the material published in enclosed articles covers the following specific topics:

1. Photoalignment of liquid crystals molecules in capillaries (papers H1, H2, H5)
2. Optical and electro-optical properties of liquid crystals infiltrated capillaries and micro-structured fibers (papers H3, H4, H6, H7, H8)

Specifically, the publications H1 and H2 are concerned with molecular orientation of ferroelectric liquid crystal in micro-capillaries and photonic crystal fibers via optical processing with UV light. This is an extension of an earlier known technique to capillaries. In the paper H1 authors show that desired orientation of molecules of ferroelectric liquid crystal inside microchannels can be achieved by first filling the capillary with a dye and its subsequent illumination with UV light of a given power and polarization. By using a double exposure authors could also achieve spatially periodic orientation of liquid crystal along the micro-channel.
This is a valuable result as it provides a repeatable and reliable approach which can be used to fabricate future devices based on liquid crystals infiltrated photonic crystal fibers and capillaries. In fact, its successful application for alignment of ferroelectric liquid crystal inside the capillary to guide linearly polarized light, has been demonstrated in H2. Application of external voltage across the capillary allowed authors to control the polarization state of guided light varying it from linear to circular.

In the subsequent work (H5) authors consider again photoaligned ferroelectric crystal within photonic crystal fiber. They study its transmission spectra and electro-optic response. They demonstrate shortening of rise and fall times of electrical signals, compared to the case of fibers filled with nematics. This result coincides with earlier results reported in the literature and hence, it is not clear if photonic crystal fiber geometry plays any role in it.

In the remaining papers H3- H8, Dr. Budaszewski and co-authors investigate experimentally the effect of doping nematic liquid crystals inside capillaries with various types of nanoparticles, including silver, gold and titanium dioxide. They study changes of physical and optical properties of liquid crystal infiltrated photonic fibers. These works represent good quality research and contain few interesting results.
Firstly, (paper H3) the authors dope nematic 6CHBT liquid crystal with silver nanoparticles and observe changes of the rise time of electric response as a function of concentration of nanoparticles. The most interesting outcome of this work is almost 50% reduction of the rise time of electric response. Additionally, authors report on 30% reduction of Fredericks threshold with higher concentration of silver nanoparticles.
Similar studies are presented in publication H4. However, this time liquid crystal is doped with gold nanoparticles. Decrease of rise time of electric signal by some 30% has been reported. No apparent influence of geometry on this effect has been identified nor discussed.

Paper H6 deals with electro-optic properties of photonic crystal waveguide infiltrated with nematic liquid crystal doped with gold nanoparticles. Blue shift of spectra with temperature has been observed but was unrelated to geometry. The most interesting result is reduction of some 80% in electric response time attributed to changes of spontaneous polarization. In addition, 60% reduction of Fredericksz transition compared to undoped nematic liquid crystals was reported. These results have not been related to photonic crystal fiber geometry but rather represent general properties of liquid crystals.

Paper H7 cover studies of optical and thermal properties of photonic crystal fiber infiltrated with gold doped ferroelectric liquid crystal. Among others, authors observe blue shift of transmission spectra with temperature and appearance of defects in molecular orientation for higher concentration of gold nanoparticles. The shortening of response time compared with undoped liquid crystal has been also reported.

Finally, publication H8 contains a quite comprehensive experimental study of optical properties of photonic crystal fibers infiltrated with ferroelectric liquid crystal doped with titanium dioxide nanoparticles. They again applied the same photoalignment technique to orient molecules of liquid crystal within the fiber. Authors report shift of transmission optical spectra with temperature and concentration of nanoparticles. However, the nature of this shift is not discussed further. Authors observe shortening of switching time by some 30% with doping level of 1% and low value of applied electric field. They attribute this effect to changes of spontaneous polarization observed in the same work.

Since all papers included in this Thesis represent joint works it is difficult to determine exactly Dr. Budaszewski's degree of independence and leadership in these projects. However, based on contribution statements from all co-authors, it appears that Dr. Budaszewski played a leading role in all but one (H4) papers. He was also a first and corresponding author in those publications. Regarding the H4 paper it should be stressed, that even though he was not a leading author, Dr. Budaszewski contributed significantly to the experimental side and provided a working hypothesis to explain the effect of gold nanoparticles on electro-optic properties of liquid crystals in capillaries.

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Dr Budaszewski provided a clearly written summary of main outcomes of each paper constituting the Thesis. Unfortunately, he did not present the proper context for each publication making the correct evaluation of significance of each work difficult. However, some conclusions regarding this point could be inferred going over each publication.

Consequently, I find that the enclosed articles do not contain real breakthrough or milestone results. They mostly extend already known concepts to the photonic crystal fiber geometry. However, they still represent solid, good quality research. Pity some interesting ideas mentioned in the Thesis, such as studies of periodic molecular reorientation for application in optical filters (paper H1), have not been pursued further. Nevertheless, the articles do contribute towards understanding of the propagation and control of light guided in capillaries and photonic crystal fibers infiltrated with liquid crystals, as well as the effect of their doping with nanoparticles. These works also confirm Dr. Budaszewski as a mature scientist and skilled experimentalist, capable to lead and carry good quality experimental research projects, efficiently collaborating locally and on an international arena. The papers have attracted a decent number of citations confirming their usefulness to scientific community.

While with a little hesitation, I thereby confirm that the Thesis fulfils the basic requirement for earning Dr. Budaszewski degree of habilitated doctor.

Yours sincerely

W. Krolikowski

Professor Wieslaw Krolikowski, FOSA, Dr. h.c. (DTU)