Delft University of Technology

Delft, 20 décembre 2010

To whom it may concerns,

I received a month ago, the copy of the doctoral thesis "*Development and applications of near-field imaging methods in the terahertz spectral domain*" written by **Mr. Milan Berta** for consideration. After a long and attentive lecture of the manuscript, I would recommend this thesis to be defended by the doctorant.

This thesis presents all the requirements to be approved as it is. It offers to the scientific community many new aspects to measure and analyze the near-field at THz frequencies of various samples.

In the first chapter, the doctorant starts with an introduction on the terahertz (THZ) radiation, the sources and detection schemes. He continues with an extensive description of the state of the art of near-field measurement methods for the THz domain. He reports the different technics used showing his mastering of the subject. This first chapter is an excellent introduction for any student who wants to study this subject.

In the second chapter, the author introduces his experimental probes from the fabrication to the description of their properties (dimensions, index, etc..). His approach to use silicon and teflon probes is the continuation of a previous work done in the same group. But the author shows how he has decided to improve and develop the concept. He continues with the description of the experimental set-ups that he has built to perform his near-field measurements. He tried to improve the coupling of the incident wave inside the probe with not much success to his despair. He describes his use of computer simulations tools. Then he makes intelligible his extensive use of data analysis. His method appears to me as a premiere to use such complex multivariate analysis in the field of THz. He clearly shows the procedure to apply this method in spite of the complexity of it.

In the third chapter, he compiles all the results obtained during his thesis. He first starts with previous results obtained in his lab, then continues with his own. He studies the noise that the measurements can carry and explains how he attends to reduce or remove them.
He carefully analyse the field he gets at the end of his tip. He made the distance to the tip varying, in order to see which components of his analysis is connected to the near field and which to the far field. He is aware of the issue of strong field localization at the edge of the waveguide that indeed creates two sensing areas.

The author carries on with actual measurements of various samples to determine their properties using his method. He shows convincingly that he can resolve difference of refractive indices therefore distinguish the samples even covered with a plastic foil.

The authors finally proceed to a complicate and challenging measurement on $BaTiO_3$ domains. Using the sensitivity of his near-field imaging method he tries to reveal local anisotropy in ferroelectrics. The polarization sensitivity of the probe to the orientation of the domain is demonstrated with great success. He presents clear evidence of it with many 2D imaging scans of the samples. A surprising results is put into our attention: the spatial resolution of his measurement is smaller than the size of his probe. The doctorant adds electromagnetic simulations of the domain stripes to explain this behavior. The conclusions of this important part are that the combination of his near-field probing set-up and his statistical approach to analyze the data allows to resolve more details than any other technics at this date. At the end of chapter four, he gets back to his concept of dual probes. Despite the difficulties to fabricate such probe, the doctorant was able to demonstrate its use to

Optics Research Group, Department Imaging Science & Technology, Faculty of Applied Sciences
Delft University of Technology - PO Box 5046
2600 GA Delft, The Netherlands
✎: a.j.l.adam@tudelft.nl
PHONE: + 31.15.2782455 • FAX: + 31.15.2788105

distinguish samples with various dielectric properties but unfortunately not with the same signal/ contrast than the one obtain with the single probe.

In the last chapter, the doctorant summarize all his findings in a concise and intelligible way.

I will have questions to raise to the doctorant regarding the relation between the multivariable statistical approach and the properties of his samples (p.60+), the set-ups (p.48), the modeling (p.85), the $BaTiO_3$ measurements (p.104) and the dual probe (p.115).

Concerning the quality of the writing and grammar used by the authors for whom english is not his native language, I would like to express my best compliments. The structure and the clarity of the thesis is also to be regarded as of high quality even I have been sometimes troubled by the ordering of the subsection. In overall the present thesis is pleasant to read and should be recommend to future students as an example.

To my knowledge, the approach of the doctorant which consists of using a probe (silicon or teflon) for near-field terahertz measurement is unique. Furthermore he is the first one to employ the multivariable statistical method that he borrowed from other fields. It shows the great advantages to use such approach when the signals you've measured are to difficult to analyze directly. In conclusion this near-field technique can have potential in biology where no contact is allowed or for other type of reflection measurements. The resolution obtained can definitely be improved in the future by reducing the size of the probe. This work is therefore of great interest for our community and even beyond. The authors clearly shows his ability for a creative and thorough scientific work.

I will be delighted to join the jury to challenge the doctorant regarding his work.

Sincerely,

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Dr Aurèle ADAM

Optics Research Group, Department Imaging Science & Technology, Faculty of Applied Sciences
Delft University of Technology - PO Box 5046
2600 GA Delft, The Netherlands
✎: a.j.l.adam@tudelft.nl
PHONE: + 31.15.2782455 • FAX: + 31.15.2788105