SINTEF

QCod - Joint Tests Summary for NIR Transmission

VERSION
V1

DATE
2017-11-30

AUTHOR(S)
Marion O'Farrell

Jon Tschudi

CLIENT(S)
Norwegian Seafood
FHF

CLIENTS REF.
Rune Hansen
Frank Jacobsen

PROJECT NO.
102014247

NO. OF PAGES AND APPENDICES:
6

ABSTRACT
This report details the results obtained using the NIR transmission set-up, during the joint tests for nematode detection in the QCod project (901246), which was funded by FHF.

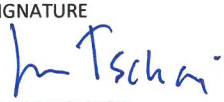
The technology applied for these tests was near infrared transmission imaging. The technology was chosen based on findings in literature that showed that nematodes and fish have different scattering properties and the hope was that this would increase the contrast in the images between nematode and fish.

The main finding is that a likely detection depth was 10mm and therefore imaging form both sides is recommended. It is also recommended to include a method such as fluorescence to reduce the likelihood of false positives at the surface. Fluorescence could be detected using the same camera if shorter NIR wavelengths were chosen.

PREPARED BY
Marion O'Farrell

SIGNATURE


APPROVED BY
Jon Tschudi

SIGNATURE


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CLASSIFICATION
Unrestricted

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Contents

1 Introduction

This report details the results obtained using the NIR transmission set-up, during the joint tests for nematode detection in the QCod project.

Originally, the near infrared (NIR) set-up was expected to comprise a moveable glass plate, NIR illumination and an InGaAs detector camera. NIR was chosen based on findings in literature that showed that nematodes and fish have different scattering properties and the hope was that this would increase the contrast in the images between nematode and fish. However, based on the initial feasibility study in the project, where a feasibility detection depth was shown to be approximately 10mm, it was decided that further improvements should be made to the set-up by expanding it to include wavelengths in the silicon detector range. This was due to the potential for significantly reducing the commercial cost if measurements were proven to be possible in this range. An additional camera and illumination were therefore included since it was in Marel's interest to explore lower-cost options.

The purpose of the joint tests was to determine the performance of 850nm (silicon), 1050nm and 1300nm (InGaAs) and compare it to other methods such as fluorescence and hyperspectral interactance imaging. The images were taken and analysed and a discussion of the potential performance is provided.

This work relates to project QCod 901246 , which was funded by FHF (Fiskeri og Havbruksnæringens forskningsfond). The project owner is Norwegian Seafoods.

2 Measurement Prototype

SINTEF was responsible for building a prototype that could test NIR transmission measurements for the detection of nematodes. The set-up was designed, built and tested at SINTEF, OSLO. It was then disassembled, packed, shipped and assembled at Nofima, Tromsø for the joint-test.

Three wavelengths were tested during the joint-test: 850nm, which was measured using a silicon camera from Dalsa, and 1050nm and 1300nm, which were measured using an InGaAs camera from XENICS. The LED modules include the LEDs, holder, collimating lens and a linear diffuser, producing a collimated beam with reasonably even illumination within a limited area. A LED driver was built using an Arduino microprocessor board that allowed each LED to be cycled on and off consecutively at a selectable rate. Since the LEDs and camera was not synchronised, a rather slow rate of 2.5 seconds on time was chosen for each LED. Photographs of the set-up are shown in figure 1. The settings for each camera are shown in the table below.

Table 1: The settings for the two cameras used.

	Silicon Camera **DALSA GENIE NANO-M1930-NIR**	**InGaAs Camera**
Lens:	RICOH FL-CC1614-2M	Edmund #83-167: 50mm SWIR
Filter	Edmund #86-446, 700nm SWIR LP	Edmund #64-693: 975nm LP
Integration time:	5ms and 20ms	100 and 500ms
F stop	5.6	2.8
Usable Field of View	30 x 75mm	30 x 75mm

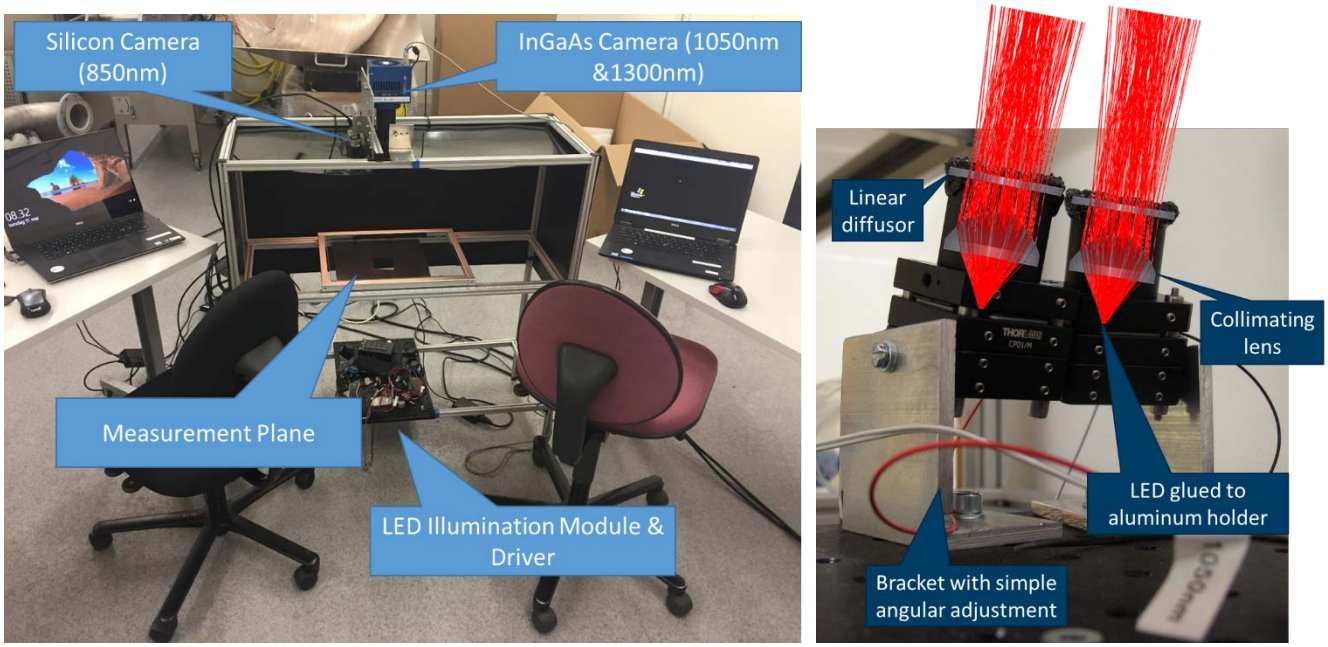

Figure 1: (a) Total set-up that was shipped and assembled in Tromsø (b) Close up of LED modules (2 LEDs shown)

3 Results & Discussion

The following fish were measured using the NIR transmission set-up: A1, A5, B3, B4, C1, C2, C4, C9, D1, D3. All of the fish were measured without any packaging and A1, C1, D3 were measured again with vacuum packaging. The three main results are described as follows

1. Transmission imaging is highly sensitive to gaping, especially at 1300nm. It interferes with the integrity of the scattered signal and induces high variation in the image. Vacuum packing improves this variation by compressing it away. In an online situation, this may be achieved by measuring on a clear plate with the camera under the fish instead of over the fish, as was done for these experiments. Figure 2 shows how gaping affects the transmission image. This is especially visible on the left side of the image, where the image is more noisy before vacuum packing.

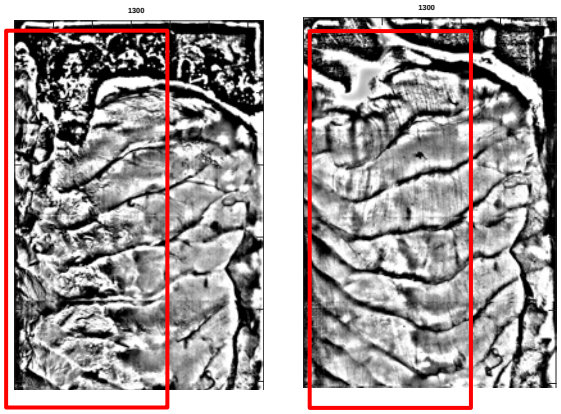

Figure 2: Comparison of same fish before (left) and after vacuum packing (right) using 1300nm. The red square shows reduced texture variation after vacuum packing.

2. The worms can be more clearly visible using transmission and we see worms that are deeper under the surface than interactance and fluorescence allow. Figure 3 compared to NIR transmission with fluorescence. Worms are visible due to their higher scattering properties relative to the fish muscle. The worms appear as shadows (low intensity regions) in the image. The worms are clearer in the transmission image. Some are only visible in the transmission image.

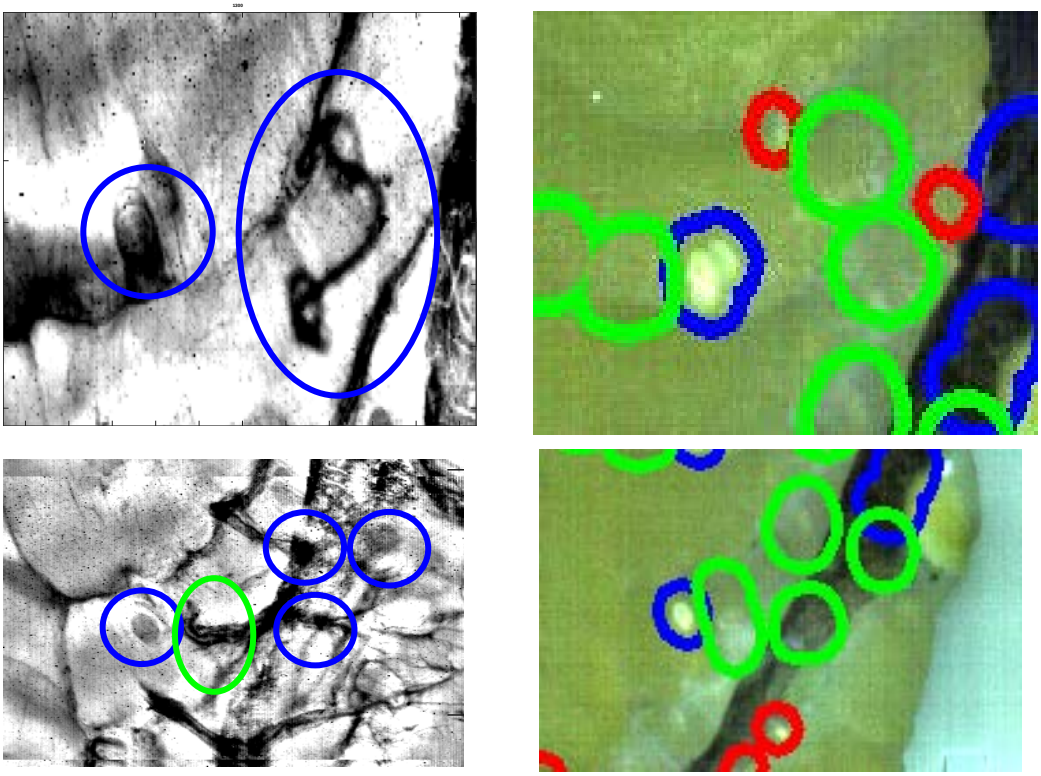

Figure 3: Transmission image (1300nm) of C1 fish (left) compared to fluorescence image of the same fish (right) - Blue is correctly detected, red is a false positive and green is undetected

3. Blood spots, gaping, black lining and skin interfere with the image and make it more challenging to detect the worms. Figure 4 shows some examples of interfering textures/objects, which introduce low-intensity regions on the image. Note also that the natural segmentation in the fish also introduce low intensity lines in the image, which also interferes with the cleanness of the background relative to the worm.

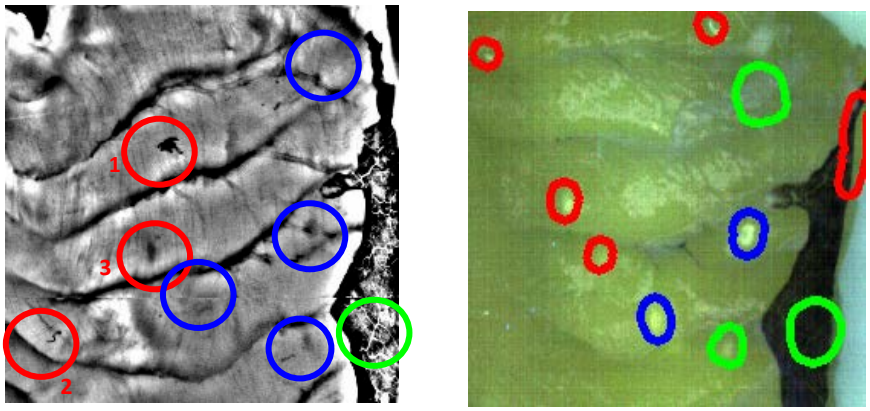

Figure 4: Transmission image (850nm) on the left and fluorescence on the right. The red circles are false-positives. The true-positives are circled in blue.

4 Conclusion

The conclusions are as follows:

- While the detection depth was greater and the structure of the worms were more visible for the transmission setup than for interactance and fluorescence, the transmission set-up would not allow 100% detection. We estimated that the maximum worm depth that could be measured is approximately 1cm. This is an issue for thicker fish.
- 1300nm is less scattered by the fish, resulting in higher contrast for deeper nematode. However, it is also more absorbed by the fish, making it more dependent on thickness and gaping. 1050nm is less sensitive to interfering parameters such as black lining (pigment in the fish) and 850nm is less sensitive to textural variation in the fish. While this robustness to background variation is an advantage, it must be considered that 1050nm and 850nm will not have as good contrast for the nematode as 1300nm. This balance must be further investigated.
- There is potential to use NIR wavelengths in the less costly silicon range up to about 1050nm, which gives the potential for a lower cost solution and therefore a double-sided measurement (i.e. from measurements from above and below). Measuring from above and below would allow for a higher detection rate as you would cover approximately 1cm from each side.
- Transmission measurements are effected by interfering parameters such as textural variation (gaping) and blood spots. Where possible, these variations should be minimised.

5 Recommended Next Steps

To practically implement and improve the measurements the following things should be investigated.

1. The camera should be placed under the fish on a clear surface, so that the camera is presented with a smooth fish surface. If feasible, measuring on vacuum packed fish is recommended as this reduces background texture variation.
2. The combination of 850nm/1050nm with other silicon-region wavelengths or fluorescence method should be investigated since the same silicon camera can be shared for these methods. In the current investigation, fluorescence was measured with a hyperspectral camera but a simpler system with a silicon camera and filters could also produce good fluorescence images. Silicon cameras are far lower in cost than InGaAs.

Combining the transmission and fluorescence measurement methods (fusion) could improve the visibility of nematodes. For example

- Deeper nematodes are more visible in transmission (as shown in figure 3).
- We know very dark spots on the transmission images are on/very near the surface (e.g. circle 1 and 2 in figure 4a). Fluorescence will easily determine if these are worms or not and can be used to eliminate false positives in the transmission images
- Since a silicon greyscale camera is a low cost solution relative to InGaAs and hyperspectral imaging, it would be feasible from a cost perspective to image from both sides, which would further help finding deep nematodes