

Locating Oil-Water Interfaces in Process Vessels

EPA Grant Number: R827015-01-0

Title: Locating Oil-Water Interfaces in Process Vessels

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Project Period: June 14, 2001 to November 30, 2001

Project Amount: \$19,982

Research Category: Separations

Description:

Introduction:

In the first half of the project, the goal was to evaluate the maximum possible pressure resolution attainable using differential detection methods and a receiver utilizing spatial demultiplexing. A test procedure was outlined in the project proposal and QA narrative to determine the maximum resolution. This report describes the procedures performed to date to meet the goals and the results obtained.

Receiver Optimization:

Difficulties Encountered:

This part of the project is taking longer than anticipated. The primary reason for the delay is an unanticipated difficulty with the computer facilities in the laboratory. First, we did not receive the correct drivers for our CCD camera, and therefore could not access camera data for a week until the correct drivers were located and installed. Second, the computer we were using for image acquisition and data processing fatally crashed, leaving us with no means to collect data from the camera. A new computer was ordered and configured, which cost two weeks of project time. Third, conflicts between the software and the security measures in place on our network cost another week of time to track down and eliminate before all functions of the image acquisition software package could be accessed. Thus, about a month of project time was lost to computer difficulties. Please note that some data is missing because one copy is being extricated for the hard drive of the crashed computer, and the other is on a computer that is temporarily inaccessible as the department is making changes in the labs in preparation for the new semester.

The second difficulty encountered was in obtaining a satisfactory grating for the receiver. The key grating property is the linear dispersion – the wavelength change required to move the imaged spot 1mm at the input plane of the camera. While it is very possible to make a grating with the properties we require, we have not yet found a company who will make ones for us. Typically this is because the company does not want to interrupt a large production run for a small order. We have obtained gratings with less-than-optimal properties to continue forward with the project.

Results To-Date:

1. Differentiating Oil and Water

While we were unable to obtain data from our camera, we proceeded to use our existing receiver, based on an optical spectrum analyzer (OSA), to determine whether our sensors could differentiate between oil and water. The maximum resolution of the OSA is 10pm, which is larger than the anticipated resolution of the new receiver by about a factor of 10. However, following the procedures outlined in the QA narrative, we are able to say that the differential sensor system *is* capable of differentiating oil and water.

First, stability testing was performed, both outside and inside the test column. Data for tests performed outside the column are shown in Figure 1. Note that there were two cases in the data set where the difference in strain was $-2\mu\text{m}$ (strain here measured in terms of fiber elongation). The average standard deviation for each of the gratings is 11.2pm for sensor two (σ_{s2}) and 16.6pm for sensor one (σ_{s1}). The average standard deviation for the difference measurement is 18.1pm, which is significantly (35%) less than $\sigma_{s2} + \sigma_{s1} = 27.8\text{pm}$. Data for inside the column for two different sensor styles were obtained, both in water and in oil, with similar results. Thus, our system was quite stable over time and repetitive strain.

Two different sensor types were then tested for the ability to measure changes in water depth and boundaries between water and oil. The first type consisted of a diaphragm enclosing a chamber of air and a sensor attached to the diaphragm. Curvature and elasticity of the diaphragm material limit the sensitivity of this configuration. The second type consisted of two enclosed air chambers (floats) attached to either side of the sensor. Air chamber size is the primary limitation on sensitivity in this configuration.

Both configurations were evaluated using the procedures discussed in the QA narrative. Figure 2 shows the results of several experiments performed with diaphragm-based sensors spaced two inches apart in a column of pure water. On average, a change in depth of one inch caused a change in wavelength of 15.2pm, based on the fits to the data. Given the stability data quoted above, the system can resolve changes in water depth of slightly less than 2 inches with the sensors just two inches apart. With moderately sized floats (two small, glass sample bottles), depth changes of about one inch were measurable.

For oil-water boundary measurements, the difference between the sensor types was more pronounced. Using the diaphragm-based sensor, the boundary could only be detected reliably when the sensors were eight inches apart. At a six-inch separation, a change in the wavelength difference was observed, but the difference was less than the differential standard deviation of the sensors. Figure 3 shows the results obtained for the float sensor measurement. The floats were positioned 6 inches apart, as were the grating sensors. The data clearly shows a change in wavelength that is larger than the sum of the individual sensor standard deviations.

2. Receiver System Optimization

Just as the summer semester ended, we were able to construct a first-generation sensor system based on a dispersive grating and a CCD camera. Because the grating's dispersion was not as large as desired, we lengthened the distance between the grating and the camera using a series of mirrors, as shown in Figure 4. No lens was used in this initial configuration. A sample of the collected data is shown in Figure 5. In each picture, the center spot is the output signal, and the rest is noise. An interference pattern is noticeable along the horizontal direction (alternating bright and dark vertical stripes). This is a result of secondary reflections at the mirrors, as the mirrors we are using are optimized for 1320nm wavelengths, not 1550nm. We are in the process of obtaining the appropriate mirrors to correct this problem, although the mirrors will not be necessary if the proper grating is obtained.

Upon initial inspection of the results, we visually observe changes in the position of the signal spot between 0.5 μ m and 1.0 μ m applied stretch on the fiber. This conforms well with results obtained on the OSA. Two possibilities may explain this correlation. (1) The fiber is slightly loose within the stretching apparatus we've constructed, so that the fiber does not experience strain until 1 μ m of displacement is applied. (2) The current configuration has similar strain sensitivity as the OSA, even in its preliminary state. Experiments are being conducted to determine which hypothesis is correct.

Current Efforts:

Obviously, visual confirmation is not a substitute for using a centroid algorithm to determine the peak signal location. This analysis is also currently in process, and the results will be submitted in the next report. We are also in the process of subtracting out the background noise level to improve the calculation results. A lens will be introduced into the system shortly to improve resolution and observe smaller positional shifts. Lastly, we will continue efforts to obtain a dispersive grating better suited to the application.

FIGURES

Figure 1: Results of sensor stability test outside of test column

Figure 2: Wavelength change as a function of depth for several experimental runs

Figure 3: Sensor response in oil and water.

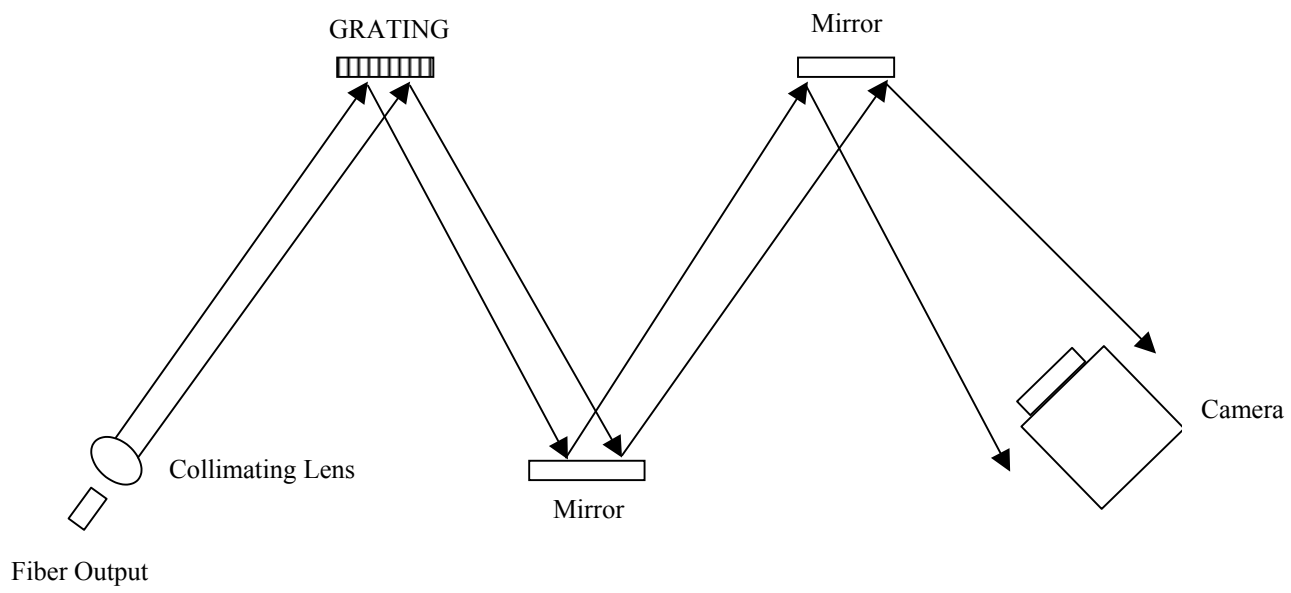


Figure 4: Extended path experimental setup

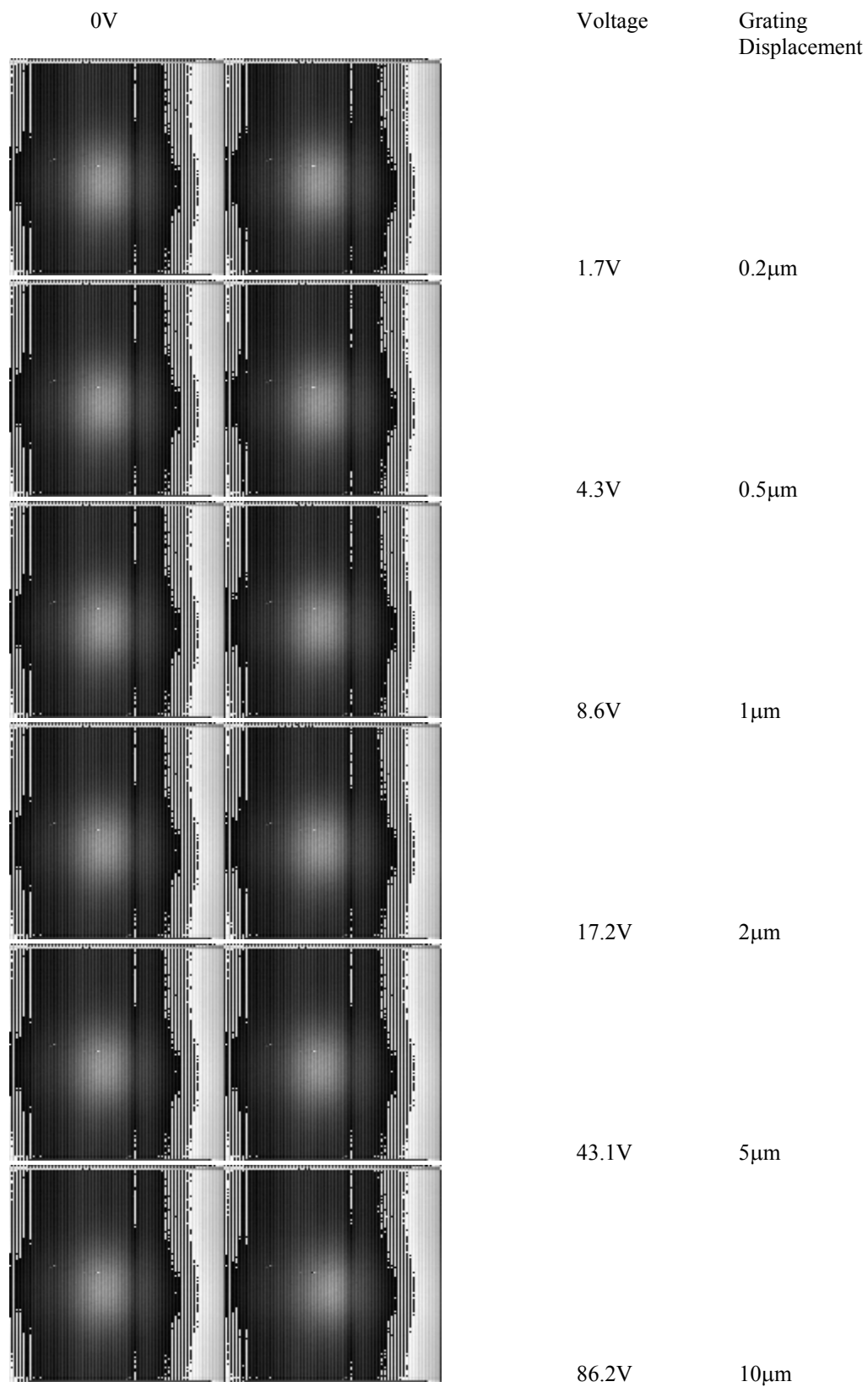


Figure 5: Preliminary camera results. Voltage = volts applied to piezoelectric stretcher.