Developing an Optical System with a Confocal Chromatic Sensor for Microscopic Robot Characterization

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Robotics is a vast and varied field, a field that is developing on the microscopic scale. Microscopic robots offer unprecedented opportunities due to their small size, smaller than what the naked eye can see. Micro-robots are primarily made of photovoltaic and operate in fluids. They move because of the generated voltage from the photovoltaic that causes controlled fluid flows that move the robot. We have a limited understanding of precise measurements of robots, specifically robot topography. A way to get the precision measurements from the robots despite their small size is to use a Confocal Chromatic Sensor, which uses controlled chromatic aberration to disperse white light into wavelengths, assigns each wavelength a distance and detects that wavelength to measure for distance. However, the sensor is severely limited: it has a small measuring range and cannot be utilized with a microscope. Here, we address this barrier by developing an optical system that collimates and refocuses the sensor beam for utilization. The optical system utilizes achromatic lenses that account for the chromatic aberration that is present in the confocal chromatic sensor. We demonstrate the success of the collimation in the system is successful by refocusing the beam back into a single point. These results are significant because this system would be used to characterize the topography of the micro robots, which will be used to gain greater knowledge on other aspects of the micro robots, like their speed, and lead to an expansion of the field of micro-robotics.

I. INTRODUCTION AND BACKGROUND

Microscopic robots are a technology that is at the cutting edge of robotics. To create robotics at that size, smaller than the resolution limit of human vision, less than 10 micrometers, a lithographic fabrication and release process is required. This process is done by taking a p-type silicon wafer and uses the processes of doping, lithography, and metallization to 'build on' the robot's circuit elements, which are silicon photovoltaics (essentially solar cells). [1] Many different types of robots can be created from this process. First, there are the 'swimmer' micro-robots that operate in fluids and solely move because of the voltage produced by the photovoltaic, which causes controlled fluid flows that move the robot. Second, there are also 'walking' micro-robots that also are in fluids, but they are moved by their 'legs', which are an added component to the robot that can propel and direct the micro-bot in the fluid. Some of these walking and swimming are programmable and able to do specific tasks. For example, some swimming robots are about to be guided by a laser system to move in a specific direction.[1] While there are many varieties and abilities of these robots, there are existing issues in characterizing them. Because of their existence at the microscopic level, it is extremely difficult to get accurate measurements on specific parts of the robots, for example, topography of the 'swimmer' robots. We can do this with a confocal chromatic sensor. A confocal chromatic sensor uses white light and focuses it on a target surface by using a multi-lens optical system. The white light is dispersed into wavelengths that show a single color by controlled chromatic aberration using the lenses in the probe. A specific distance is assigned to each single-color wavelength, and the wavelength that is focused on the target is used for the measurement. The light is reflected onto a light sensitive sensor element, like a mirror, on and the corresponding spectral color is detected and evaluated.[2] However, this tool is limited. Its range for measurement is limited to 10 mm, and as it is, it cannot be put into a microscope, which is necessary to view and later characterize the micro-robots. To address this, we determined we needed to take the sensor beam and collimate it so that it can be used in the microscope.

II. EXPERIMENTAL RESULTS

We decided to achieve this by developing an optical system. The first part of the optical system we looked at was the lenses. We decided on the use of achromatic lenses, which consist of two optical components cemented together, which are the positive low-index component, known as the crown, and the negative high-index component, also known as the flint. This design incorporated many elements of both components, which offers advantages for the lens, mostly significantly its ability to reduce chromatic aberration. [3] Since chromatic aberration is a significant element of the confocal chromatic sensor, we found that addressing its effects in the lenses was essential to our lens setup. Our first optical setup consisted of the sensor going through a coated Plano-convex lens that collimated the beam, followed by a coated Bi Convex lens which took the collimated beam and focused it back until a point. However, the focused point was quite large compared to the initial point that emitted from the sensor. We fixed this using the achromatic lenses, as we used two of the lenses to collimate and refocus the beam to a much smaller point that was visually much more like the original point emitting from the sensor, a system demonstrated **by Figure 1**. **And Figure 2**.

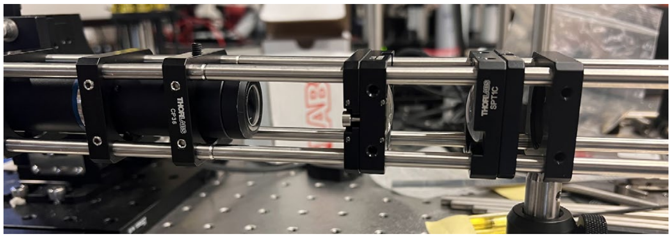

Fig. 1 Confocal Chromatic Sensor and Optical System

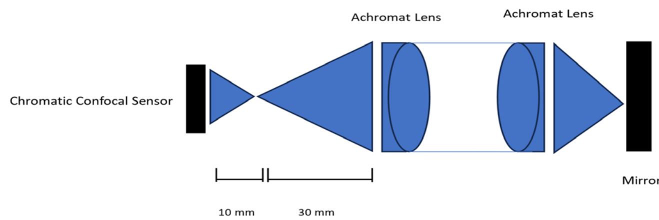

Fig.2 Light Path of Optical System

However, while we had success in the collimation area, the point focused on the end of the optical path did not have success picking up readings with the sensor tool software. This leads us to some hypotheses on why, and some conclusions about the optical system.

III. Discussion and Conclusion

Overall, while the sensor was unable to pick up reading after the beam collimation, we were able to gain valuable information from this experiment. We did have success with beam collimation, and we gained valuable insight on the confocal chromatic sensor. After some consultation with the tool manufacturer, we determined that more research was needed specifically about the lens system within the chromatic confocal sensor, and its mathematical relationship with the achromatic lens system. I hypothesize that an understanding of that relationship would further this research, and with the help of the tool manufacturer the sensor could possibly be calibrated to work with the lens system. Further work would include the research with the lenses, and also utilization of the tool with a microscope set up to get closer to the end goal of micro-robot characterization.

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