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Applications of Laser Machining for Fiber Optic Sensor Development

Student researcher: Lauren Sailor, Junior

With the volume of pollution created through energy production, manufacturing, and other industrial processes, many different approaches are utilized to limit release into the atmosphere. One approach for handling carbon dioxide (CO_2) is sequestration. With sequestration, the gas is pumped 0.5–1 miles underground, where carbon dioxide is naturally found. This process is safe, but quick leaks can be fatal, necessitating monitoring of the storage sites. Traditional sensors suffer from significant interference given the extreme conditions and depth underground, but optical fiber sensors maintain accuracy.

The sensor we developed includes hollow-core photonic crystal fiber (HCPCF) aligned with single mode fiber (SMF) on either side. HCPCF allows CO_2 to interact with the light, affecting the refractive index. These changes can be translated into a measurement of concentration. To keep the fibers aligned, they are fixed in a groove of constant depth and width around 120 micron in an engraved piece of glass. Many variables were tested to increase the control over the groove shape and size. With use of a femtosecond laser and six-axis stage, best results were found using high-pressure air blowing parallel to the glass to remove debris and angled, intermittent machining.

Considering the size of the sensor components, assembly is time-consuming and detailed work. Also, it is critical that the ends of the fiber are straight, which a mechanical cutting device cannot accomplish. The femtosecond laser resulted in perfectly straight cuts, exact cutting lengths, and reduced length of costly HCPCF. This method also allows for fixing the HCPCF to the glass before it is cut to size, which helps prevent epoxy from entering into the hollow core of the fiber. Process improvements were achieved through altering the laser machining and sensor assembly procedures—steps to advance the overall development of the underground sensor.

Research advisor Hang-Eun Joe writes: "Lauren's research is a part of the study on optical fiber sensor development for gas monitoring. This novel fabrication process is used in various types of optical fiber sensors with high precision. This optical fiber sensor has the potential to monitor CO_2 leakage at deep geological storage."

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