LOW-COST OPTICAL FIBERS MICROSCALE GRINDING AND POLISHING SYSTEM: TOWARDS OPEN-SOURCE DEVICES AND SYSTEMS

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Abstract

Open-source software, devices, and systems allow other researchers and investigators to replicate, develop and enhance the reported systems in the literature. This paper introduces an open-source system for optical fiber grinding and polishing, which facilitates and speeds up the polishing and grinding process. The polishing system is based on an Arduino microcontroller board, an open-source development board that utilizes an easy programming language enabling almost everyone to develop and write their codes and projects. In addition, the reported device targets low-cost fabrication allowing more researchers to fabricate their grinding-polishing machine. The device consists of the control circuits, stepper motor, breadboard, and a 3D-printed desk, where the polishing and grinding films should be attached. The device is controlled via 3 buttons: start/shut down button, speed up button and speed down button.

Keywords: Low-cost, open source, grinding and polishing, optical fibers, optical sensors.

1. INTRODUCTION

A recent trend in engineering is to share projects, findings, and accomplishments under open-source access. Open-source software can be defined as free software with public access to its source code so anyone can view, modify or edit its content [1]. Low-cost prototyping is associated with several open-source projects in the literature. For example, a group of researchers reported a low-cost open-source system to monitor inertia and pressure using an Arduino prototyping platform [2]. Several research groups reported low-cost open-source 3D printer prototypes [3–5].

Optical fibers are waveguides that can carry light signals for long distances and minimize power loss compared to conventional copper cables. In addition, optical fibers are immune to signal distortion and interference [6]. Optical fibers are manufactured from glass or polymers, glass optical fibers, and polymer optical fibers (POFs). Besides their conventional use in optical communications, they have been used extensively in various sensing applications [7–9]. Hence, there is an increasing demand to grind and polish glass optical fibers and POFs. Commercial optical fiber polishing machines can cost several thousands of dollars [10,11], forming a financial challenge for the research teams in the sensory field.

This study aims to introduce an open-source polishing and grinding system for optical fibers which is easy to replicate and use. The reported system automates the grinding and polishing process using a 3D-printed motorized stage. The system speeds up the grinding and polishing processes compared to using grinding and polishing films manually, as manual grinding and polishing require more time and can be less accurate on the optical fiber surface.

This paper introduces an open-source, low-cost Arduino-based optical fiber polishing stage that can use different paper polishing films to grind and polish glass and plastic optical fibers. Three push buttons can control the stage (on/off button, speed up button, and speed down button) and a graphical user interface (GUI) windows application. The paper includes the control circuit designs, and all the source codes can be downloaded from GitHub, as provided later.

2. MATERIALS AND METHODS

A- The grinding-polishing stage

The grinding polishing stage has several parts: Power supply (LONGWEI K3010D, LONGWEI Electric, China), D.C. stepper motor NEMA 17, L298N motor driver, Arduino Mega, and 3 push buttons. **Figure 1** shows the circuit design drawn by Fritzing software [12].

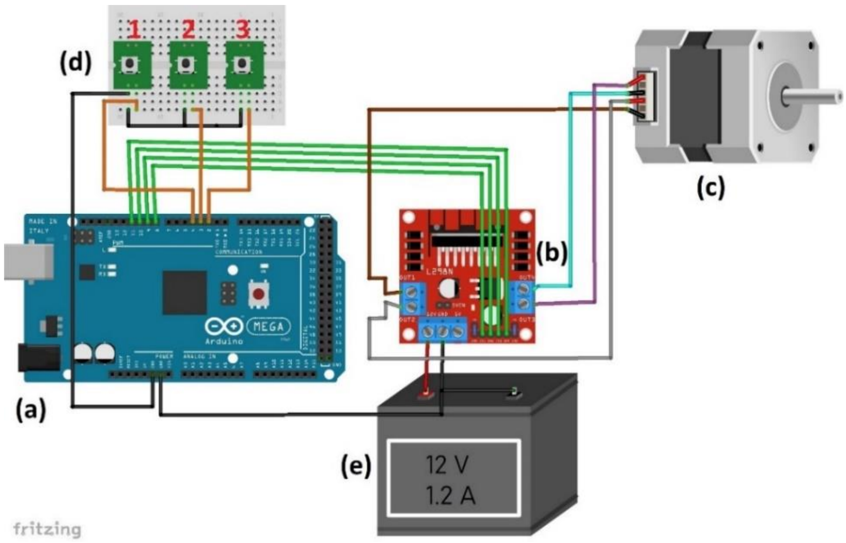

Figure 1 Grinding polishing stage electronic design: (a) Arduino Mega, (b) L298N motor driver, (c) NEMA17 stepper motor, (d) breadboard with control push buttons, and (e) power source.

A 125 mm in diameter rounded desk was 3D designed using Autodesk Inventor Professional 2018 student's version [13] the designed desk is compatible with the stepper motor to fit into the motor's axe, Prusa i3 MK3S+ 3D printed was used to print the desk, the desk was printed using a 1.75 mm (Polylactic acid) PLA filament. **Figure 2** shows the desk's design. The desk's STL file is downloadable from the Thingiverse website [14].

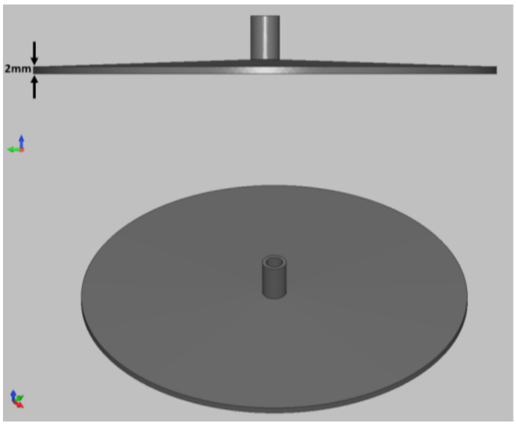

Figure 2 The polishing-grinding desk's 3D design.

The 125 mm polishing and grinding films (OPTOKON [15] films: 3µm and 5 µm diamond grinding films and Utlimas 5 final polishing films) were attached to the 3D printed desk using a double side tape.

The stage can be controlled via the 3 push buttons, as shown in **Figure 1d**. Button 1 is used to decrease the set starting default speed, button 2 is used to switch on/off the motor, and button 3 is used to increase the default speed. Setting the desired default speed is possible through editing the Arduino code, which can be downloaded from GitHub [16]. To set the motor's speed to a desired/default revolutions per minute (RPM) speed, the motor's step angle is applied in equation 1. NEMA 17 has a step angle of 1.8°, meaning it has 200 steps for each complete revolution.

$$Steps\ per\ revolution = \frac{360}{Step\ angle} \quad (1)$$

In addition to controlling the stage via push buttons, a C# graphical user interface Windows-based program can be used to control the stage; source code and the application setup files can be downloaded from GitHub [17]. **Figure 3** shows the GUI Windows-based software that controls the grinding-polishing stage through Arduino's USB cable.

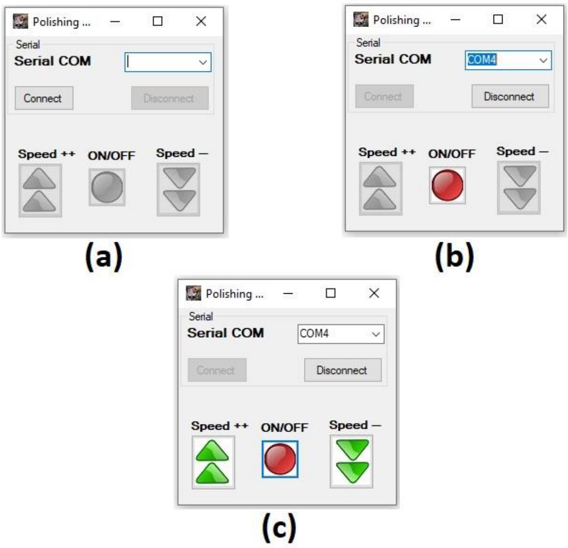

Figure 3 The control GUI software: (a) Software disconnected from the Arduino board, (b) software is connected to the Arduino board, (c) software is connected, and the motor is switched on.

Figure 4 shows the actual implementation of the grinding polishing stage according to the design in **Figure 1**.

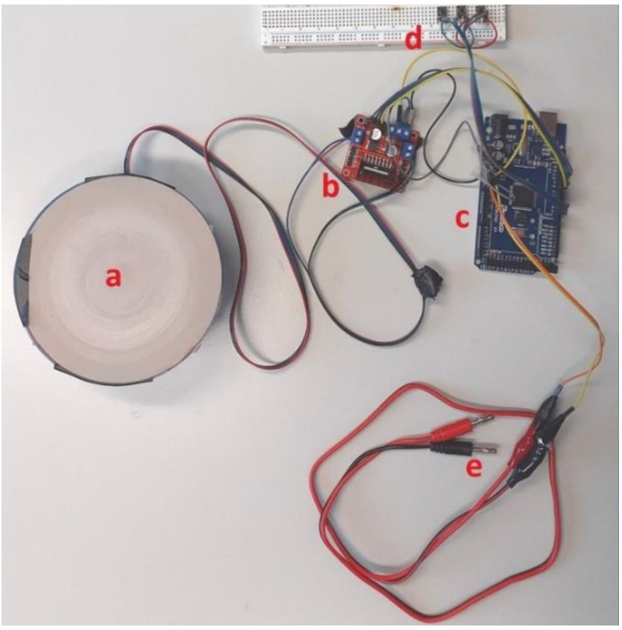

Figure 4 Implementation of the grinding-polishing stage: (a) Grinding polishing desk and motor, (b) motor's driver, (c) Arduino Mega, (d) Control push buttons, (e) Power source connections/battery connections.

B- Plastic optical fibers (POF) and signal measurements

Plastic optical fibers have several applications in sensing and communications engineering. They have several advantages over glass optical fibers as plastic optical fibers have a lightweight, require simple and cheap components, are more flexible and resilient to bending, and don't require a laser source to operate. However, POF has a higher transmission loss than glass optical fiber [18].

Two POF (PMMA 0.2 mm POF, refractive index 1.49, numerical aperture 0.5) samples of a 65 mm length with and without grinding/polishing were compared in terms of the received signal to prove the grinding-polishing stage functionality. A simple setup was constructed to send, receive, convert and amplify the photodiode's received optical signal. **Figure 5** shows the used design and its components to measure the received signal from the POF in volts; the retrieved signal is measured by a voltmeter, as shown in the figure.

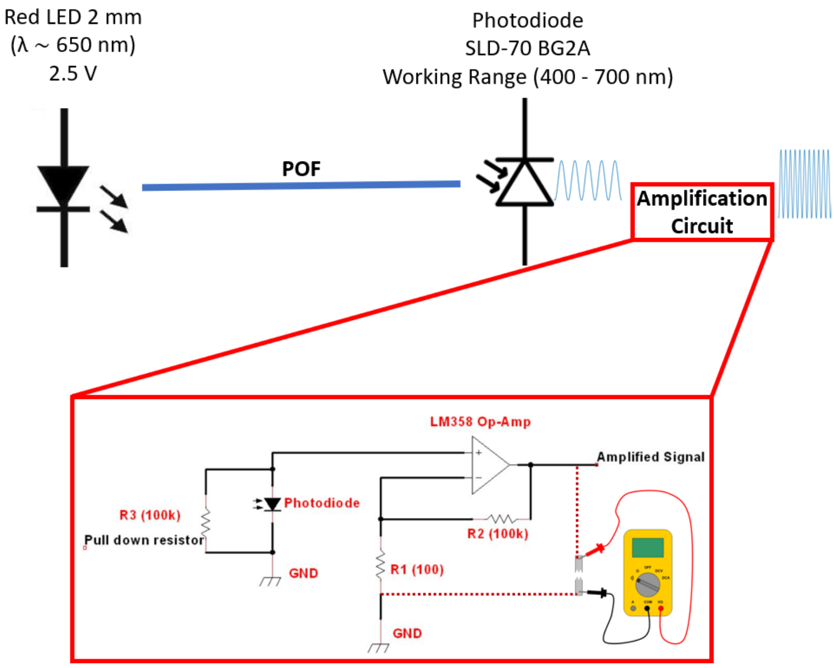

Figure 5 Signal conversion and amplification circuit

3. RESULTS AND DISCUSSION

The designed grinding and polishing stage successfully hosted commercial fiber optic films. POF sample of a 65 mm length was grinded and polished from each side for about 30 seconds at an average speed of 100 RPM; **Table 1** shows the obtained results comparing the polished and unpolished POF; the results were obtained using the setup in **Figure 4**.

Table 1 Received signal comparison of POF with and without using the stage

POF	Received Signal
Using the stage	0.78 V
Without polishing	0.24 V

The obtained results show the effectiveness of using the grinding-polishing stage as it saves processing time compared to manually polishing the fibers on the optical films.

4. CONCLUSIONS

The paper introduced an open-source grinding-polishing system for glass and plastic optical fibers; all designs and codes are available for download online, so other researchers can replicate, develop and enhance the proposed system. The system saves time and provides more accuracy and control on polishing speeds and consumed time. The results showed the system's effectiveness in improving the signal transmission over POF and decreasing the power loss due to imperfect non-polished fiber cross sections.

A promising future perspective would be incorporating more automation into the system in loading the fibers and approaching similar commercial systems but at a much lower budget to accomplish a broader concept of open-source devices.

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