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Booklets

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Title: Fiber Optic Coiling System Prototype

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Acknowledgements

Introduction

Commercial device

Figure 1. DigiSpooler II (Showmark, 2020)

Patents (USA)

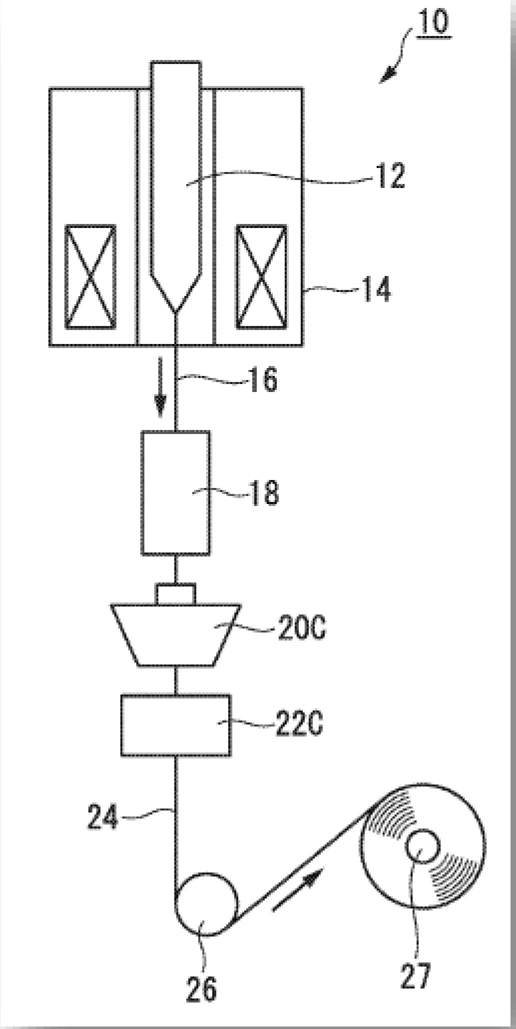


Figure 2. Bare optical fiber coating device and bare optical fiber coating method (Kowalczyk et al., 2020)

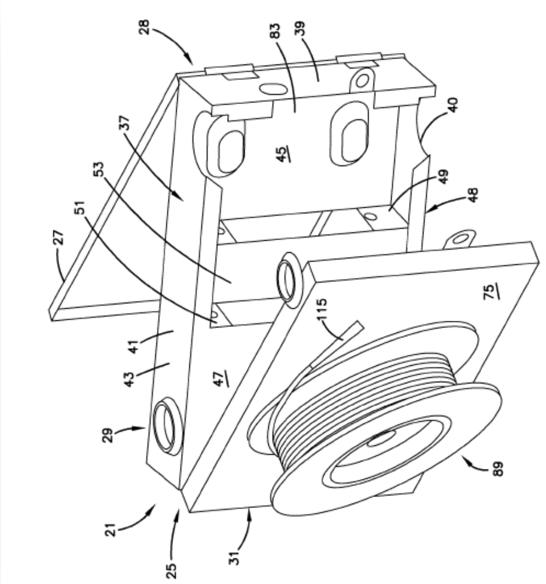


Figure 3. Fiber optic assembly with cable spool (Okada, 2020)

Operation

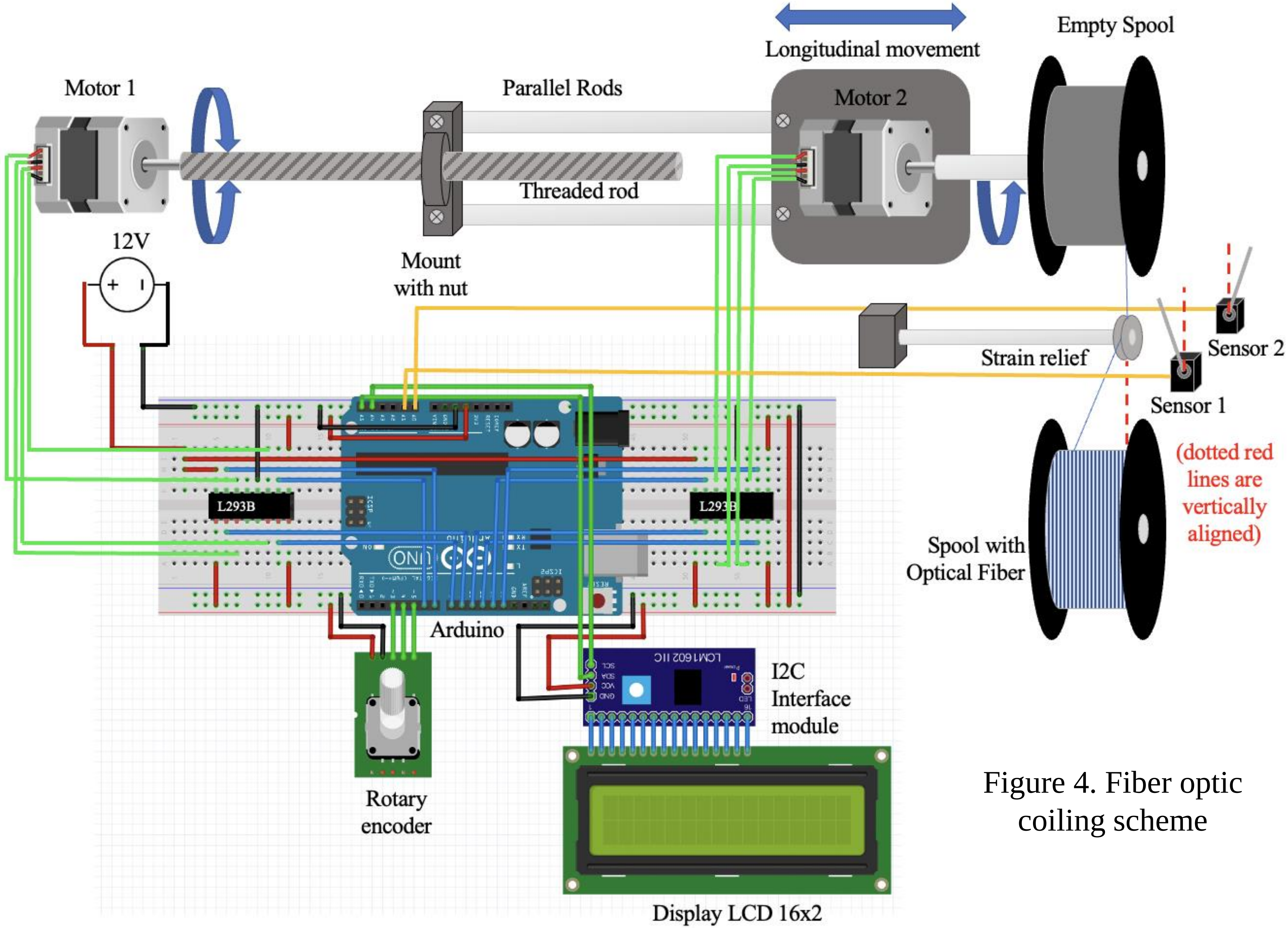


Figure 4. Fiber optic coiling scheme

Mathematical model

In order to know the fiber length in a single revolution on the spool, the expression for the perimeter of a circle $l = \pi d_s$ is used, where l is the length and d_s the spool diameter.

This expression can be generalized for any revolution number N obtaining a fiber length L:

$$L = N\pi d_s. \quad (1)$$

Thus, depending on the number of complete layers n, the diameter will increase according to the relation:

$$d_n = d_s + 2nd_f. \tag{2}$$

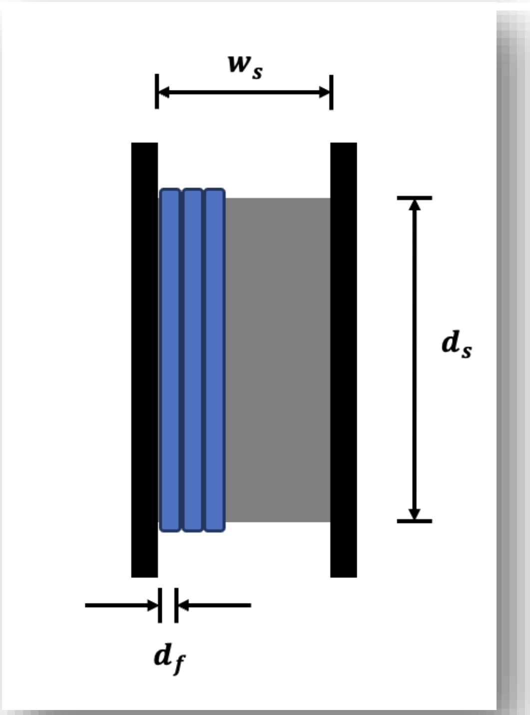


Figure 5. Fiber with diameter d_f coiled on a spool with diameter d_s and width w_c (lateral view)

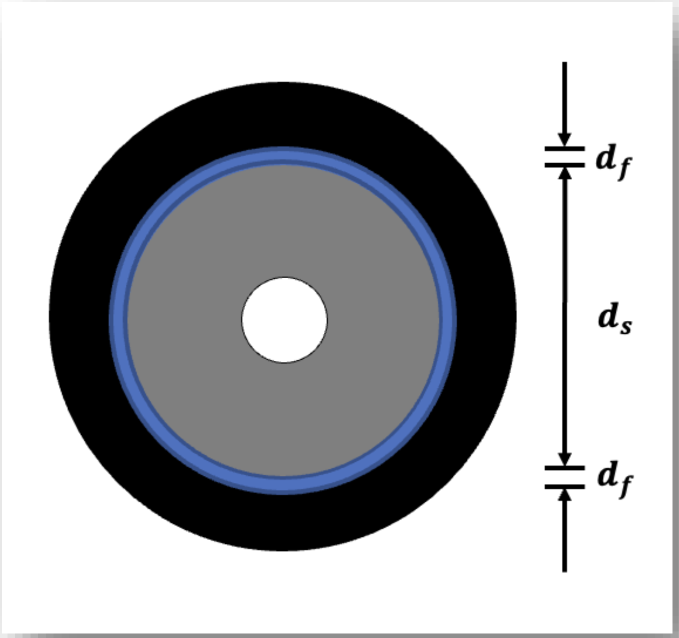


Figure 6. One single fiber layer on the spool (transverse view)

the number of revolutions N can also be represented:

$$N = \frac{w_s}{d_f}. \tag{3}$$

Substituting (3) in (1) and considering the diameter increase for each layer of (2), a layer-by-layer analysis can be performed in the form:

$$L_1 = \frac{w_s}{d_f}\pi d_s, \qquad 1st\ layer \tag{4}$$

$$L_2 = \frac{w_s}{d_f}\pi[d_s + 2d_f], \qquad 2nd\ layer \tag{5}$$

$$L_3 = \frac{w_s}{d_f}\pi[d_s + 2(2d_f)], \qquad 3rd\ layer \tag{6}$$

$$\vdots$$

$$L_n = \frac{w_s}{d_f}\pi[d_s + 2(n-1)d_f]. \quad layer\ n \tag{7}$$

In this way, to obtain the length of complete layers:

$$L_c = \frac{w_s}{d_f} \pi \sum_{i=1}^{n} [d_s + 2(i-1) d_f]. \tag{8}$$

To calculate the remaining length L_r, it follows:

$$L_r = N\pi(d_s + 2nd_f). \tag{9}$$

Then, the total fiber length L_T is:

$$L_T = L_c + L_r. \tag{10}$$

Associated error

if you want to calculate the uncertainty of an indirect measurement z that is given by $z = x + y$ or $z = x - y$, then the uncertainty associated with this variable is:

$$\Delta z = \Delta x + \Delta y. \tag{11}$$

On the other hand, if you want to calculate the uncertainty of the product $w = x \cdot y$, the uncertainty associated with w is given by:

$$\Delta w = |y|\Delta x + |x|\Delta y. \tag{12}$$

From (11), the uncertainty or associated error with the coiled length given by (10) can be obtained, then:

$$\Delta L_T = \Delta L_c + \Delta L_r. \tag{13}$$

there is an error associated with the limit switch sensors pressing changing the direction of longitudinal movement when completing a full layer of fiber on the spool, this error causes the number of fibers inside the spool not to exactly correspond to the mentioned ratio. Therefore, the ratio w_s/d_f must be substituted as an independent variable c.

Thus, by (12), the associated error ΔL_c is:

$$\Delta L_c = c\pi \sum_{i=1}^{n}\left[\Delta d_s + 2(i-1)\Delta d_f\right] + \\ + \Delta c\pi \sum_{i=1}^{n}[d_s + 2(i-1)d_f]\,. \qquad (14)$$

On the other hand, the associated error ΔL_r is:

$$\Delta L_r = N\pi\left(\Delta d_s + 2nd_f\right). \qquad (15)$$

Finally obtaining:

$$\Delta L_c = c\pi \sum_{i=1}^{n}\left[\Delta d_s + 2(i-1)\Delta d_f\right] + \\ + \Delta c\pi \sum_{i=1}^{n}\left[d_s + 2(i-1)d_f\right] + \\ + N\pi\left(\Delta d_s + 2nd_f\right). \qquad (16)$$

Final prototype

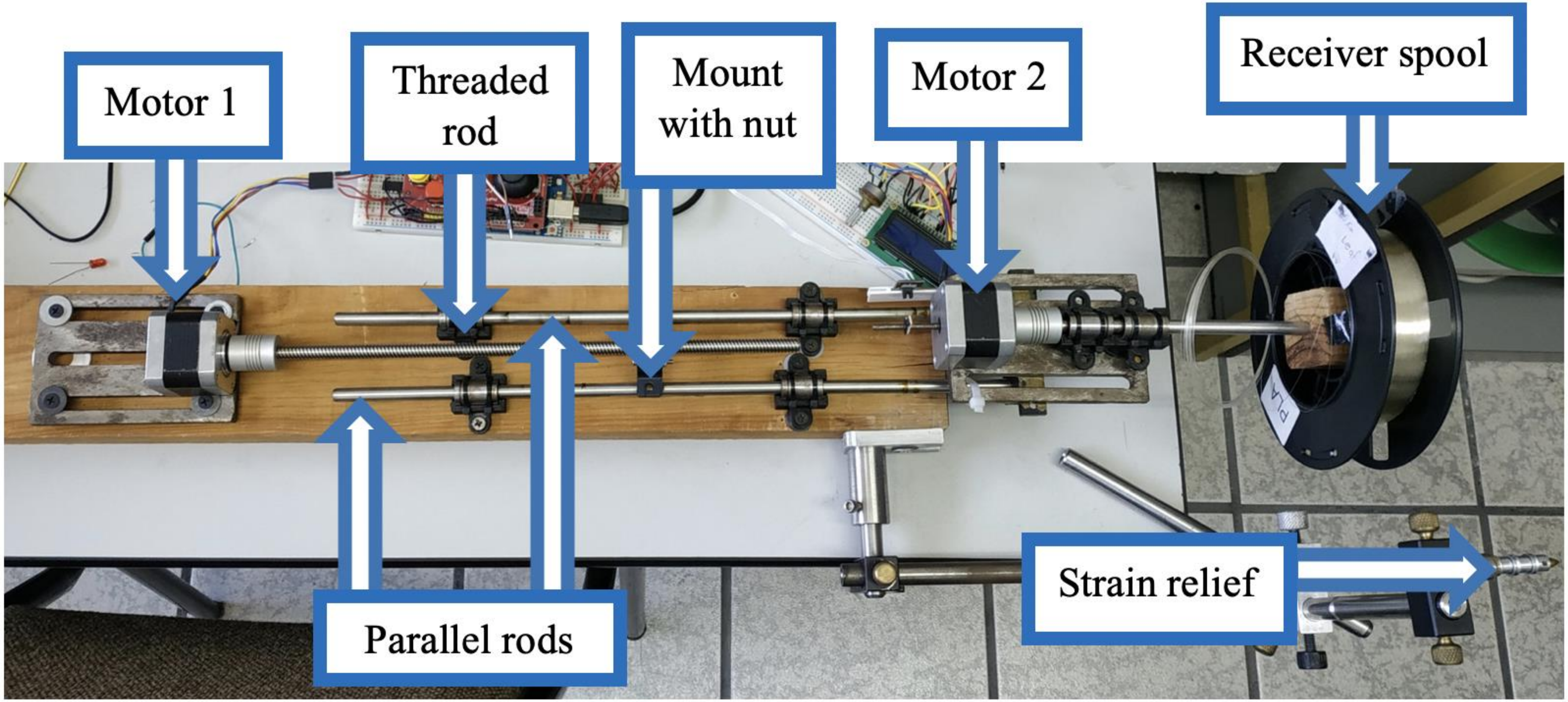
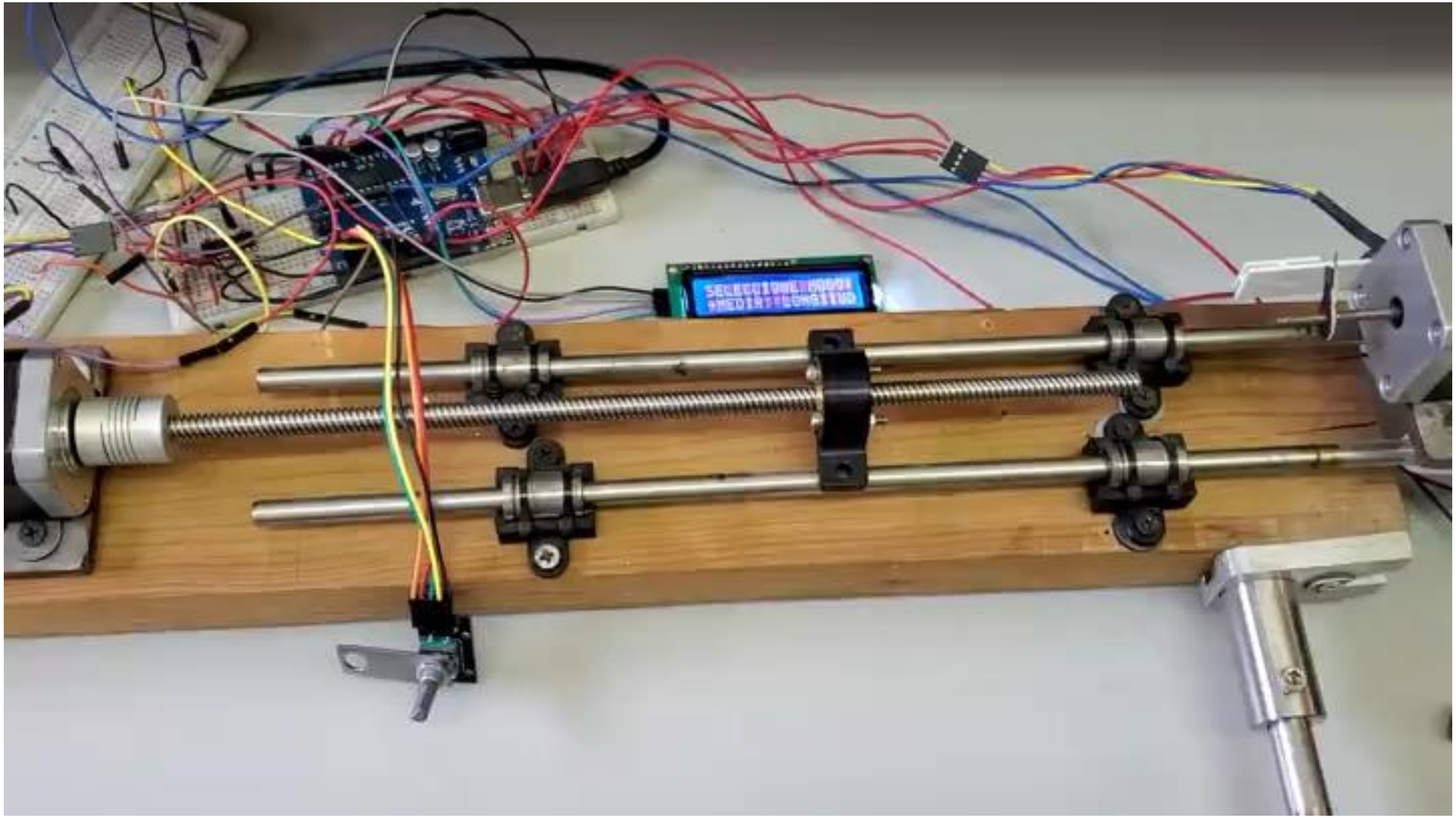


Figura 7. Fiber optic coiling components



Future improvements

Minimize error sources

Improve resolution

Improve machine performance

Conclusions

Prototype fully automated

Low-cost prototype

Adaptable system with adjustable functions

Functional and reproducible machine capable of coiling and measuring large amounts of optical fiber in a controlled, uniform and homogeneous manner

Contribution to technological production in México

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