INTERNATIONAL JOURNAL OF ENERGY and ENVIRONMENT
DOI: 10.46300/91012.2021.15.18 Volume 15, 2021

Synchronization and Power Unit Controller for CO_2 Laser Cable Marking System

S.Messaoud, F.Siserir, Y.Boucetta, M.Traiche, L.Henni, B.Guedouar
Ionized Media and Laser Department
Center of Development and Advanced Technologies, CDTA
Algiers, Algeria

H.Okay
Technical Department
Best Cable
Algiers, Algeria

Received: June 28, 2019. Revised: July 7, 2021. Accepted: October 12, 2021. Published: November 26, 2021.

Abstract— **In this paper, we describe the design of the synchronization and power unit controller (SPUC) for CO_2 laser cable marking system inline-processing. It is mainly composed of a synchronization and modulation control circuits. Power control of output laser beam is achieved by pulse width modulation (PWM). The synchronization between the CO_2 laser, the rotating mask disk and the pivoting mirror is performed by a Lab VIEW based program and National Instruments (NI).**

Keywords— ***CO_2 laser; laser marking; PWM; labVIEW.***

I. Introduction

Laser marking provides the best alternative to non permanent cable marking such "Ink Jet" or to the aggressive marking methods like "Hot Stamping". It produces a permanent high-contrast mark without damaging or affecting the integrity of the cable insulation [1, 2, 3,]. The laser marking experimental set-up used consists of [4]: RF-excited CO_2 Laser operating at 10.6 µm in pulsed mode, a rotating mask with character or number apertures as masks disposed all around at regular steps, a pivoting mirror for scanning the beam parallel to the running direction of the cable, a beam expander, a system of mirrors for steering the beam, a focal lens, a rotary encoder, a synchronization and power unit controller (SPUC) and a PC to manage the whole set-up. Added to that, a guiding cable support is made up of five flat-bottomed pulleys keep the surface marked at the same level. The system will be integrated into the cable production line after the cooling sink and dryer stages. It must be isolated from external vibrations and must works with a fume extraction system for the user safety.

In this first part of our work the design and function of the SPUC for RF-excited CO_2 Laser cable marking system will be fully described. The experimental results will be also presented and discussed.

II. Description of SPUC

A schematic diagram of SPUC is shown in Fig. 1. The SPUC is the main unit of the electronic control system. It is mainly composed of a synchronization and modulation control circuits. Its functions consist of [5]:

- Controls laser average power by providing a variable duty cycle signal (from 0% to 100%) to the laser.
- Provides tickle level (1µs) that keeps the plasma pre-ionized to achieve fastest possible response.

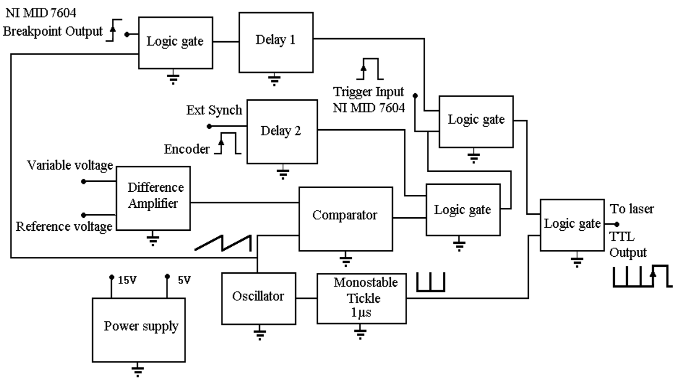


Fig. 1. Schematic diagram of SPUC.

- Activates the laser beam to illuminate the selected character which is thus marked on the electric cable. The laser triggering signal (TTL) is provided by a stepper motor drive NI-MID 7604 through the Breakpoint output connection.
- Sends appropriate signals to the trigger input connection of the stepper motor drive to control the rotating movements of the mask and the pivoting mirror through the NI-PCI 7344 card.
- Synchronizes the rotating movements of the mask and the pivoting mirror with the laser frequency by using a LabVIEW based program and instruments (NI).

The SPUC is driven by the marking triggering signal (TTL) generated by a rotary encoder in combination with a measuring wheel, to measure the length of moving cable (length marking).

A. Modulation control

The SPUC controls laser average power by providing a variable duty-cycle signal to the laser source [5]: the control is from 0 to 100 % of maximum. A schematic diagram of modulation control circuit is given in Fig. 1. Power supply delivers 15 V, 5 V respectively to the circuit, 0.5 A fuse element protects the circuit. The oscillator stage is the master clock (5 KHz). The output waveform is square. The monostable stage is triggered by the master clock and provides tickle signal required for RF excited CO_2 laser. The triangular signal delivered by the master clock is applied to a comparator

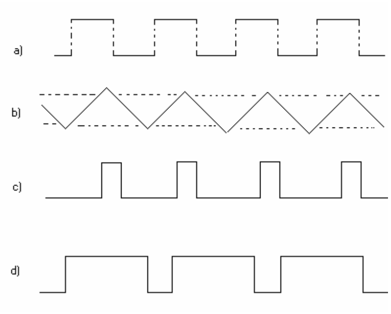


Fig. 2. Variations of modulation waveform versus the time.

stage; the other input of comparator is a DC signal which varies from 1.6 V to 3.3 V. This signal is provided by an error amplifier stage which compares the variation of manual voltage to the fixed reference voltage. Whenever the DC voltage signal exceeds the triangular signal voltage, the output of comparator drops to TTL high level with a variable duty cycle signal. The tickle signal is connected to a logic gate (OR), the other input to this gate is from the output of a logic gate (AND) which generates the variable duty-cycle signal. The logic gate output (OR) is applied to drive RF excited CO_2 laser. The Variations of modulation waveform versus with the time is given in Fig. 2, a): signal delivered from master clock; b): triangular signal and DC signal (discontinued lines) applied to the input of comparator stage; c): modulation waveform from the output comparator (duty cycle 25 %); d): modulation waveform from the output comparator (duty cycle 75 %). The external synchronization function allows driving the SPUC by an external TTL signal.

B. Synchronization control

The synchronization control is required to ensure a good working of the cable marking system. The synchronization between the laser source, the rotating mask and the pivoting mirror is performed by NI instruments motions controller (PCI-7344), a stepper motor power drive (NI-MID 7604) and a Lab VIEW based program. The marking triggering signal (TTL) generated by a rotary encoder is applied to the trigger input of the NI-MID 7604 module trough a delay circuit (2) and a logic gate (AND) of SPUC. The delay circuit (2) fixes a marking time of de-magnified images of the mask characters on the surface of the cable. During this time, the rotating mask and pivoting mirror are controlled by the NI PCI-7344 board is connected to NI-MID-7604 power drive. The mask stepper motor is used to move a rotating stainless steel mask between laser pulses to position each character aperture in the path of the laser beam. A pivoting mirror under the control of a stepper motor is used to switch from one series characters to the other that reflects the beam parallel to the running direction of the cable. The speed of a stepper motors is synchronised with the laser frequency. The laser beam is activated to generate the selected character on the cable. The laser triggering signal is provided by NI-MID 7604 module (Breakpoint output) trough a delay circuit (1) and logic gate (AND) of SPUC. The delay circuit (1) fixes the exposure time of the laser. The waveform of control signals is given in the Fig. 3, a: marking triggering signal; b: delay (2) output signal; c: comparator output signal; d: Breakpoint output signal; e: delay (1) output signal; f: laser triggering signal with tickle pulse.

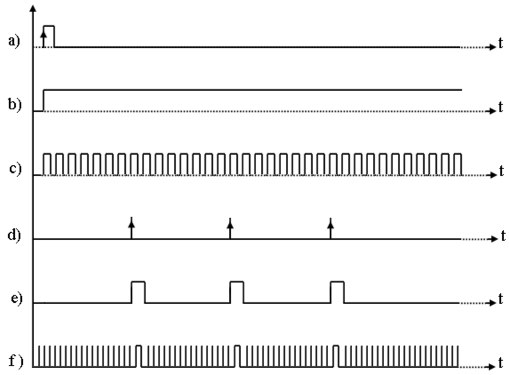


Fig. 3. Waveform of control signals vs the time.

The LabView based synchronization program is developed for detecting the trigger input signal from SPUC and moving the rotating mask between successive angular positions in synchronization with the pivoting mirror [6,7]. Also allows the pivoting mirror to return to the initial position after each end of marking operation. The program generates the breakpoint signal from MID 7604 module for activating the laser beam to transfer the image of selected character on the surface of the cable. The front panel of the application is represented on the Fig. 4.

III. Experimental results and discussion

The schematic diagram of the experimental set-up is given in Fig. 5. The power measurements were made with a laser power meter (power wizard TM 250), Tektronix oscilloscope (TDS 3052) and a function generator (GX 245). Using the RF excited all–metal CO_2 laser (SYNRAD, Model: 48-2-28), the measurements of laser output power and modulation signals have been made for several values of duty cycle with fixed modulation frequency (5 KHz). Figure. 6, shows the laser output power varies proportionally with duty cycle for fixed modulation frequency (5 KHz). Figure. 7, shows the variation of modulation signal for several values of duty cycle. The tickle signal required for RF excited CO_2 laser is given in the Fig. 8.

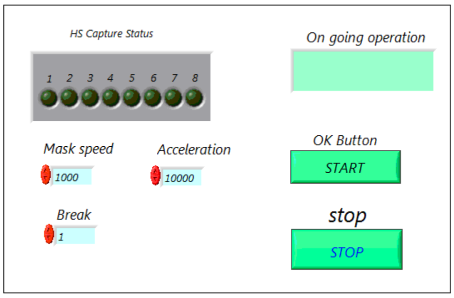


Fig. 4. Front panel of the application.

In this experimental work, the marking triggering signal (TTL) generated by a rotary encoder is simulated by a function generator (5 V, 1Hz). This signal is applied to the delay circuit input (2) trough the external synchronization of SPUC

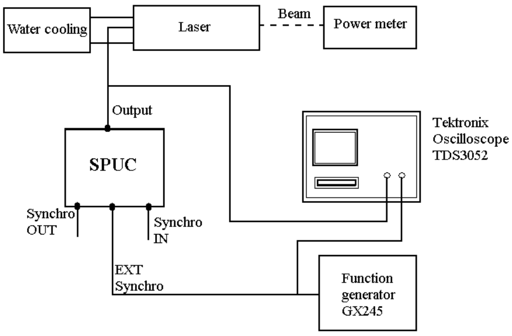


Fig. 5. Schematic diagram of the experimental set-up.

as shown in Fig. 9, (upper trace). The output signal (lower trace) delivered by a delay circuit (2) is shown in the Fig. 9. This signal is applied to a logic gate (AND), the other input of this gate is connected to the output of comparator which generates the variable duty-cycle signal as shown in the Fig. 10. The trigger input signal provided by a logic gate (AND) to the MID 7604 is given in Fig. 11. The output signal (lower trace) delivered by a delay circuit (1) is shown in the Fig. 12. The circuit PCB of SPUC is represented by the Fig. 13.

The marking time of a series characters on the surface of cable is fixed by a delay circuit (2). According to the Fig. 9, the measured value is about 40 ms (lower trace). This time depends on the modulation frequency (5 KHz), the numbers of character apertures machined on the mask and the step numbers between successive angular positions. It must be less than to the period of marking triggering signal which depends of the running speed of the cable (60m/mn) and the length marking.

The exposure time of the laser is also fixed by a delay circuit (1). According to the Fig. 12, the measured maximum value is about 200 µs (lower trace). This time depends of the value of duty cycle signal (from 0 to 100 %) with fixed modulation frequency. The rotating stainless steel mask contains two sets of 25 alphanumeric characters. A stepper motor (working in micro-stepping mode) is used to move the mask between laser pulses to position, each character aperture in place before the next laser pulse arrives. In order to achieve this, a high speed stepper motor with trapezoidal profile is used and the inertia of the mask minimized.

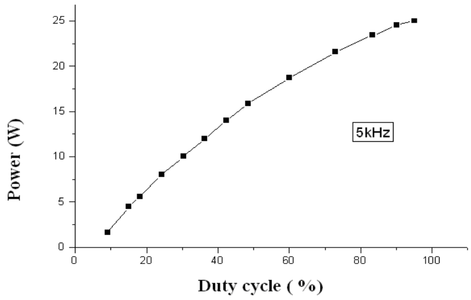


Fig. 6. Dependence of output laser power on duty cycle.

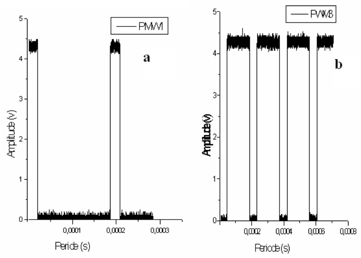


Fig. 7. Variations of modulation waveform vs the time.
a) 10%, b) 75 %

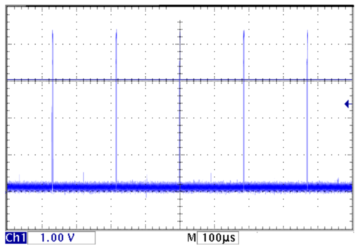


Fig. 8. Tickle signals (1 V/div, 100 µs/ div).

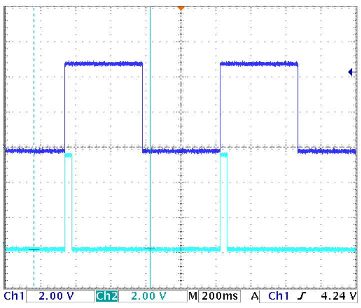
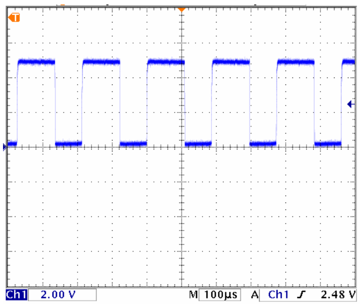


Fig. 9. Delay circuit (2) output signal (2V/div, 200 ms/ div).



DOI: 10.46300/91012.2021.15.18

Fig.10. Variable duty-cycle signal (2 V/div, 100 µs/ div).

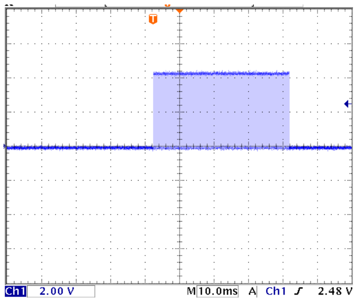


Fig. 11. Trigger input signal (2V/div, 10ms/ div).

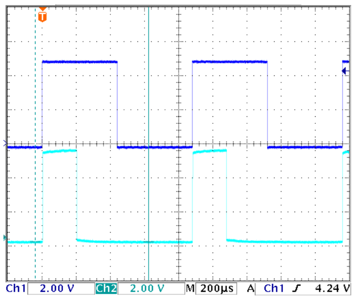


Fig. 12. Delay circuit (1) output signal (2V/div, 200 µs/ div).

Fig. 13. Circuit PCB of SPUC.

IV. Conclusion

We have described the design and function of the SPUC. The controller has been designed to provide necessary control of the laser average output power by adjusting duty cycle signal at a fixed modulation frequency. The laser power level can be gated by an external TTL signal. The controller provides tickle signal that keeps the plasma pre-ionized to achieve fastest possible response. The controller provides the required signals to ensure the synchronization between the CO_2 laser, the rotating mask and the pivoting mirror. The developed LabView based synchronization program permits to detect the trigger input signal from SPUC and generates positions control pulses of the rotating mask and the pivoting mirror. The program provides the breakpoint signal to activate the laser beam to generate the image of selected character on the surface of the cable.

References

[1] Australian governement civil aviation authority, Hot stamp wire identification, Air worthiness bulletin, (2007).

[2] Haack, K.Kurz, and G.Lauck, Non-contact marking by laser beam, Hoechst AG, N°7, pp 878.-882, 1993.

[3] P.Dickinson ,J.Davies, UV laser wire marking technology review and update, Aerospace electrical interconnect système symposium,(2007).

[4] S.Messaoud, M.Traiche, F.Siserir, Y.Boucetta, A,Senadjki, B.Guedouar, H.Okay, CO_2 Laser marking system for printing electric cables inline-processing, 15 th Internationale Conference on Laser Optics (LO'12), Russia, 2012.

[5] G.Zhenhua, S.Messaoud, G.Xin, L.Yimen, P.Leonov, RF-excited CO_2 laser with IR-optical fiber, International Conference on Industrial lasers (IL' 99),SPIE Vol 3862, China , 1999, pp 183-186.

[6] Gary W.J., Labview Graphical Programming, Montreal, Mc Graw Hill, 1997.

[7] Cottet F., Labview : programmation et applications, Dunod édition, 2001.

E-ISSN: 2308-1007