40514 - High power 2 µm wavelength fiber laser for precision weeding

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Introduction

We present a new generation of fiber lasers operating in the 2 µm wavelength range that provides the highest available output power with single mode beam quality. Due to administrative regulations and customer demands herbicide usage in agriculture must be drastically reduced in the future. Fiber laser systems emitting at 2 µm wavelength offer many benefits for precision herbicide free laser weeding e.g., high absorption in plant tissue, small focus spot diameter and high overall efficiency. The laser wavelength is overlapping with a strong water absorption peak, which provides high absorption in all kinds of weeds [1]. The penetration depth of a few hundred µm enables highly efficient weeding. With energy doses provided by millisecond pulses the regrows of weeds is suppressed [2].

Objective

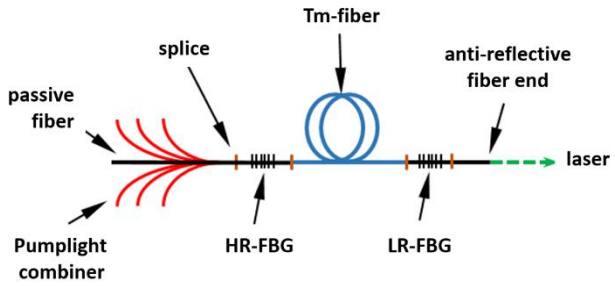
Weed control is one of the most important objectives for crop production with high output yields. Weeds typically only constitute a small proportion of the target area, and herbicide application increases the risk of environmental contamination, as most herbicides hit non-target material or are lost to spray drift. Also, problems with herbicide-resistant weeds are increasing worldwide. The negative side-effects of pesticide use have resulted in stricter regulation and political initiatives to reduce pesticide use [3]. Therefore, there is a need for developing new techniques supplementing or replacing present weed control methods.

A laser beam can be directed toward a weed plant and deliver high-density energy on the meristem and warm up the tissue resulting in harming or killing of the weed plant [4]. Using recognition tools based on artificial intelligence, it is possible to distinguish weeds from crop plants in real-time. The meristem can be detected using high-resolution cameras, while precise scanners can position the laser focus.

Futonics high power 2 µm laser

Here we present the actual 2 µm laser systems from Futonics, which provide output powers up to 750 W in pulsed and up to 500 W in continuous operation. The newest fiber laser systems based on an all-fiber design provide single mode beam quality over the whole power range. The all-fiber design enables a robust design without free space optics (Figure 1). This provides a stable output power and long-term continuous operation in the field. Also, the maintenance costs are minimized. Outside the laser the application fiber is protected by a metal hose and the fiber end, with its anti-reflective coated output window, which is held in a robust connector. The high beam quality in combination with the emission wavelength enables spot diameters below 200 µm at a working distance of 0.5 m. With such a working distance the beam diameter is only doubled in some cm from the focus.

Figure 1. Schematic of the "All-Fiber" design used in the Thulium fiber laser systems from Futonics

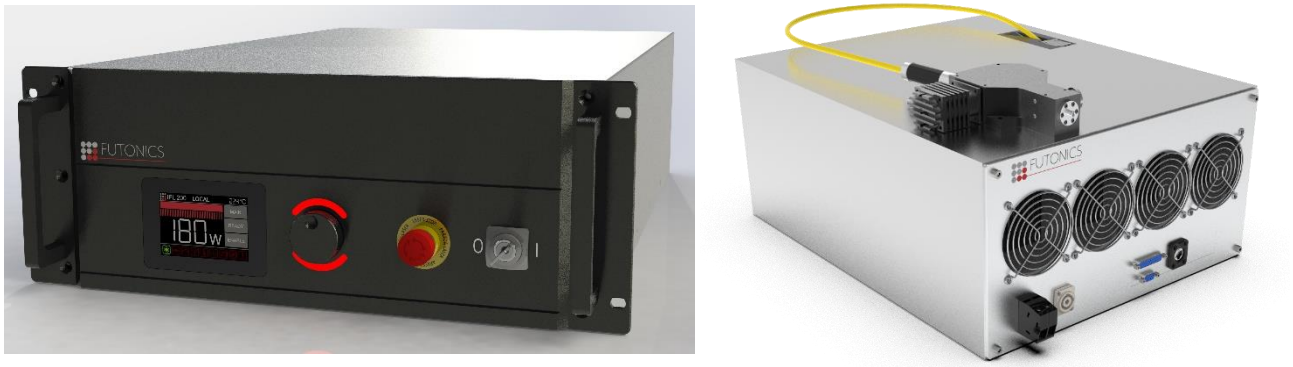


Futonics 2 µm fiber lasers reach a high overall laser efficiency, as they utilize the two for one cross relaxation process in thulium. In this process for one pump photon two laser photons are generated. Together with highly efficient fiber coupled pump diodes an overall efficiency of up to 20 % is achieved, which is significantly better compared to other weeding lasers. For operation on autonomous vehicles or other agriculture equipment the laser systems can be operated directly with the vehicle electrical system voltage of 48 V DC.

Laser weeding application

The 2 µm laser sources from Futonics are used within the WeLASER project for weed control experiments [5]. During the project water cooled systems with up to 500 W average power are tested and air-cooled systems with lower power are developed (Figure 2). The laser is mounted on an autonomous vehicle and the power is guided by fiber to an attached scanner system. Artificial intelligence is used to identify and locate crop and weed plants and direct the laser beam to the targets. A fast control electronic of the laser systems allows turning on and off of the full laser power within 50 µs. This enables precise hitting of weeds.

Figure 2. Futonics water cooled high power laser (left side) and air cooled laser (right side)



Weeds were treated with different energy densities and treatment times to analyse regrowth. In the field weed species have different temperature requirements for effective treatment. Seeds from weed species with higher temperature requirements (e.g., *Solanum nigrum* L. and *Urtica urens* L.) need longer treatment times to suppress regrowth. The best weeding results were obtained when the meristem of the target plant is exposed on the cotyledon stage or the two permanent leaf stage. At these stages, only the apical meristem is developed for most weed species. The laser spot directly hits the weed and does not trigger weed seeds to germinate on the whole area. Good treatment results were observed, because the 2 µm radiation penetrates through the epidermis of plants cells and is mainly absorbed by the water inside the plant. In contrast the energy from a CO2 laser, is solely absorbed on the surface of the plant, therefore more energy for treatment is needed.

Discussion and conclusions

Laser treatment of weeds is a suitable alternative or supplement to, for example, herbicide application or mechanical weed control. The effect of the laser treatment depends on weed species, laser spot position, growth size, laser spot area, and applied laser energy. Due to the very small laser spot diameter the area directly exposed for weed control is drastically reduced. Therefore, this method interferes substantially less with the biodiversity and environment.

Futonics high power 2 µm laser sources are ideally suited for weed control applications. The absorption of the 2 µm radiation very strong in all types of weeds. The high beam quality of the new fiber lasers enables small spot diameters in long focal distances and the design of the lasers ensures a stable operation also in harsh environments.

Acknowledgements

Major parts of the work presented here were carried out in the course of the Horizon 2020 project WeLASER (https://www.welaser-project.eu, grant agreement no. 101000256), which is gratefully acknowledged. The authors thank their project partners for the good cooperation.

References

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5. Horizon 2020 project WeLASER, grant agreement no. 101000256, https://www.welaser-project.eu.

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Laser weeding with 2 µm lasers

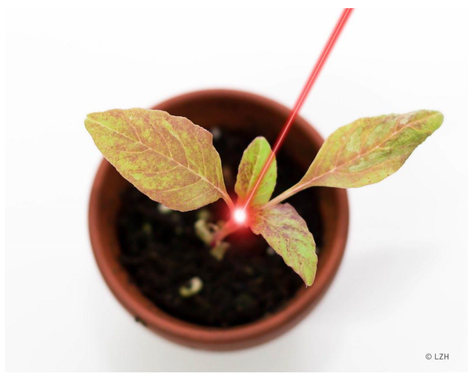
Herbicid free weed control

Autonomous vehicles for weeding

Motivation & Introduction

- Ecological weed control becomes more important
- Herbicide application causes a lot of environmental contaminations
- Herbicide-resistant weeds are increasing worldwide

→ Laser weeding as alternative method for efficient weed control



- Laser beams can deliver precisely high-density energy on a weed
- Weed meristems and tissue are heated and the weed plant is killed
- Modern recognition tools can distinguish between crop plants and weeds in real-time
- Precise scanners can position the focus of the laser very fast, avoiding unnecessary soil treatment
- Using high resolution camera, the meristem of a weed can be exact detected

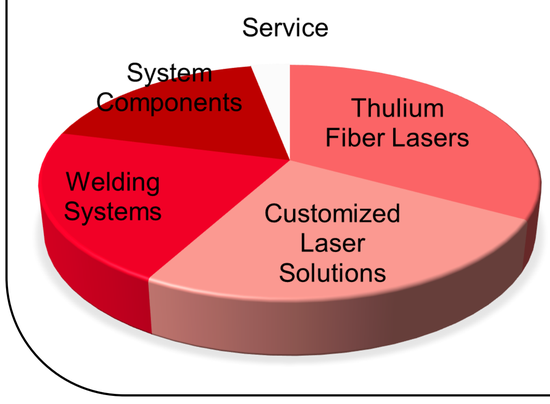
Futonics Laser GmbH

Founded 2018 at the geographical center of Germany

R&D located in Göttingen, production in Katlenburg

Actual 11 employees (5 in R&D)

Two European and three national research projects



WeLASER – Eco-innovative weeding with laser

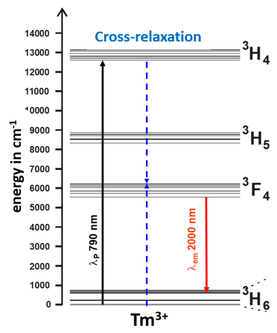
DECOMP

DigiWeed

SPITZE

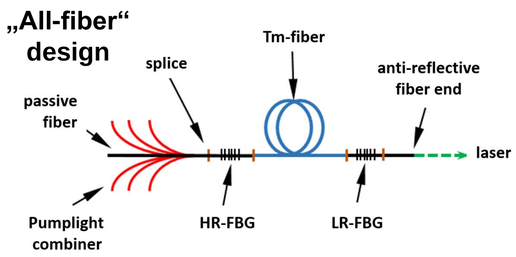
Futonics High Power 2 µm Laser

- New generation of high power 2 µm fiber lasers
- Highest output power with single mode in the market
- Up to 750 W in pulsed mode and up to 500 W cw
- High overall efficiency due to cross relaxation process



- Water cooled laser system
- 19” compatible size; 4 RU
- 48 V DC supply voltage
- Application fiber length 10 m

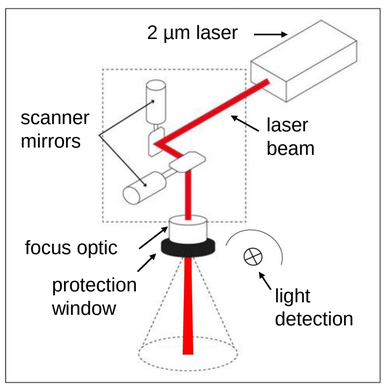
- Laser is based on a robust “all-fiber” design
- No free space optics, low maintenance costs
- 2 µm lasers with high beam quality enable spot diameters below 200 µm in 0.5 m working distance



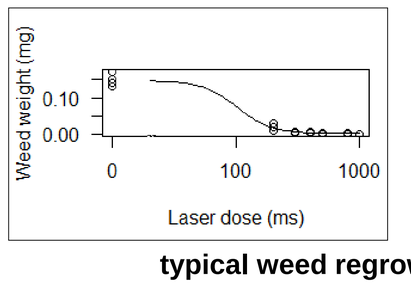
- Air cooled 2 µm system
- Pulsed up to 630 W
- Average output power 60 W
- 55x42.5x23 cm³; weight 37.5 kg

Laser Weeding Application

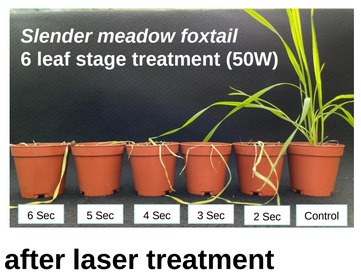
- Administrative regulations and customer demands will force to reduce usage of herbicides in agriculture
- Within the WeLASER project an autonomous weeding system with Futonics lasers is developed
- Two 250 W Futonics 2 µm lasers are used in the project for weed treatments
- Locations of crop and weed plants are identified by artificial intelligence
- High water absorption at 2 µm induces strong absorption in plant tissue
- Fast control electronics to switch laser power in some µs



- Treatment times to suppress regrowth for many different weed species were defined in WeLASER
- Optimum treatment when weed meristem is hit
- Best treatment times are the cotyledon stage or the two permanent leaf stage
- In contrast to CO2 lasers 2 µm lasers penetrate plant tissue



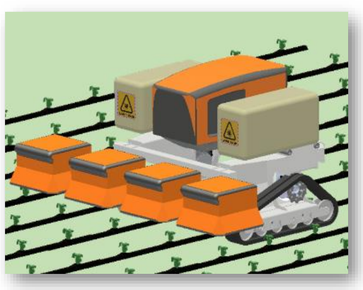
typical weed regrowth after laser treatment



Conclusion & Outlook

- High power 2 µm lasers are well suitable for weed control
- Laser with up to 650 W pulsed or 500 W cw power from Futonics
- Regrowth of weeds is successful suppressed with ms laser pulses
- Autonomous weeding developed in the WeLASER project
- Artificial intelligence used to distinguish between crops and weeds

→ In the future weeding of 200 Ar/h is achievable by using more lasers on one system



Future system for 4 row treatment

Acknowledgements

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WeLASER – Eco-innovative weeding with laser

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