The Abdus Salam
International Centre
for Theoretical Physics
50th Anniversary 1964-2014

2572-8

Winter College on Optics: Fundamentals of Photonics - Theory, Devices and Applications

10 - 21 February 2014

Photonics in surface cleaning processes (II)

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(permanent adress)

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ICTP Associate

Laser cleaning applied to food product:

Solving a Thorny Problem

Food product with thorns: The case of Nopal (Opuntia)

- From ancient times, Mexican people uses the fresh Nopal cactus leaves and fruits for human consumption.
- At present, the demand is growing due the excellent properties and quality.
- The production in Mexico is about 500,000 T per year
- The Nopal is cover by 40-80 areoles (thorns)

The benefits of nopal

- Can be grown in semi-desert
- It is important source of fiber
- As fibrous plant, Nopal contains pectin, mucilage and gums that are helpful to the digestive system.
- Controls the symptoms of diabetes achieving satisfactory stability of blood sugar levels
- Contains lots of vitamins C and E

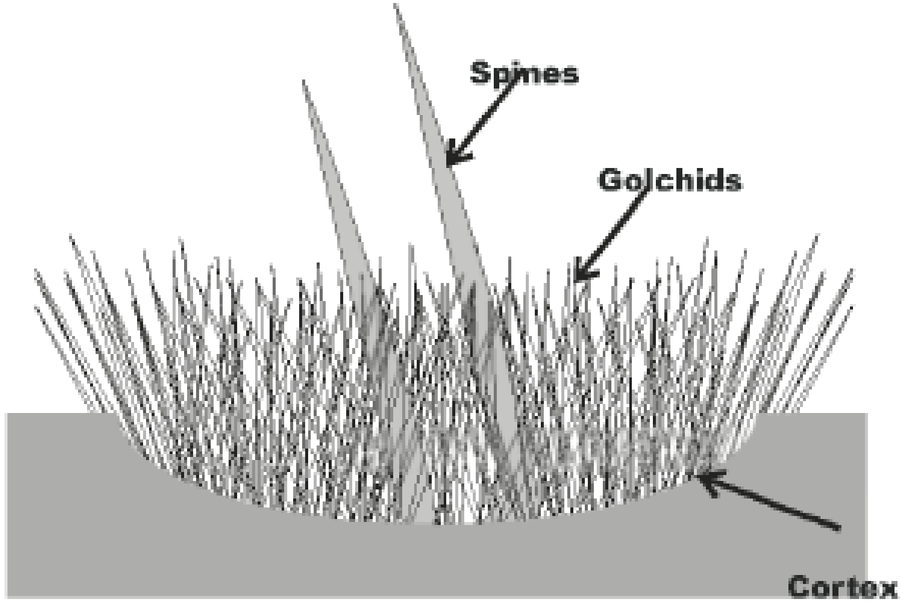
The problem: Manual removal of thorns

• Decrease in product life (only few hours !!!)
• Sanitary risk
• Losses of about 30 %
• Damage to the operators health
• Low productivity
•The problem of mucilage

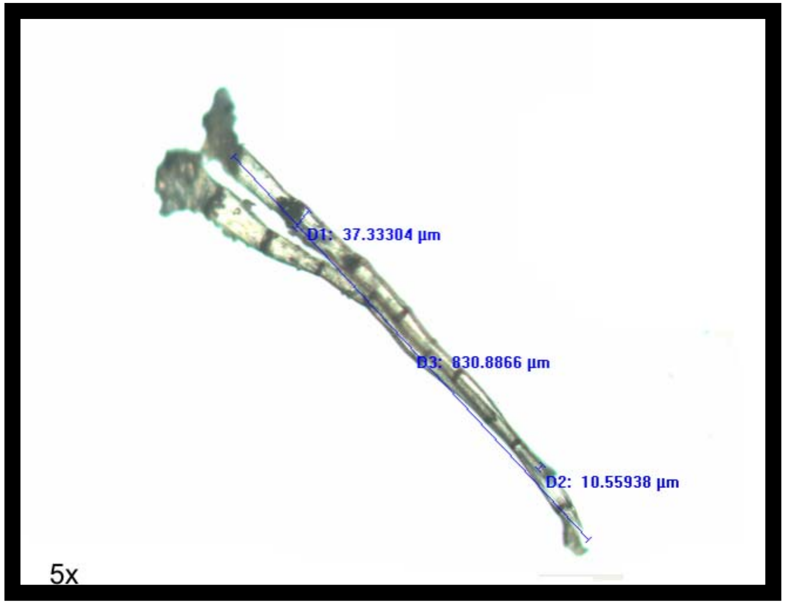
The areoles (thorns) elimination is considered a serious problem for the industry and limits the commercialization.

The global demand exceeds the current production

Description of thorns (areoles)



- The areola: Some big thorns and many small glochids surrounding the thorns



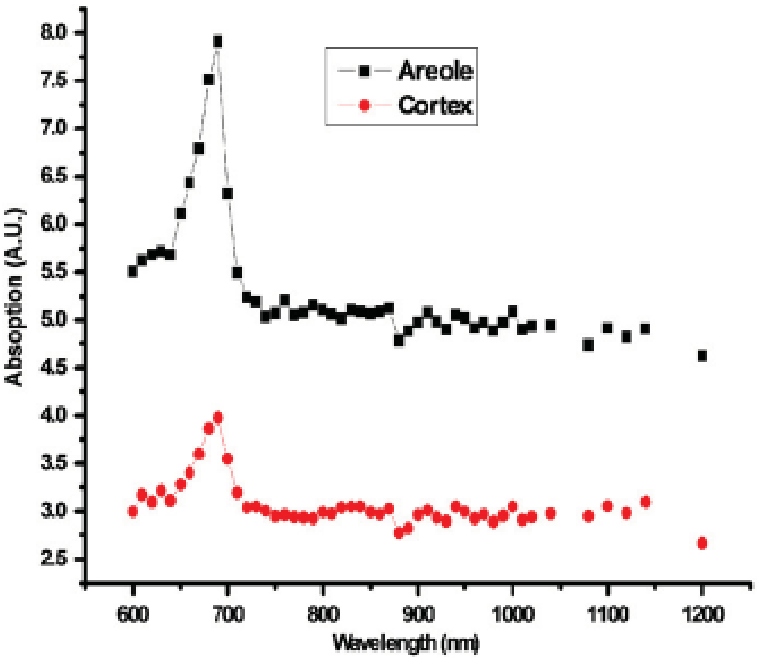
The glochids:

- Composed basically by cellulose
- They are full of water inside
- Strongly absorbs light
- Cellulose is a combustible material

The cleaning by laser ablation is the solution!

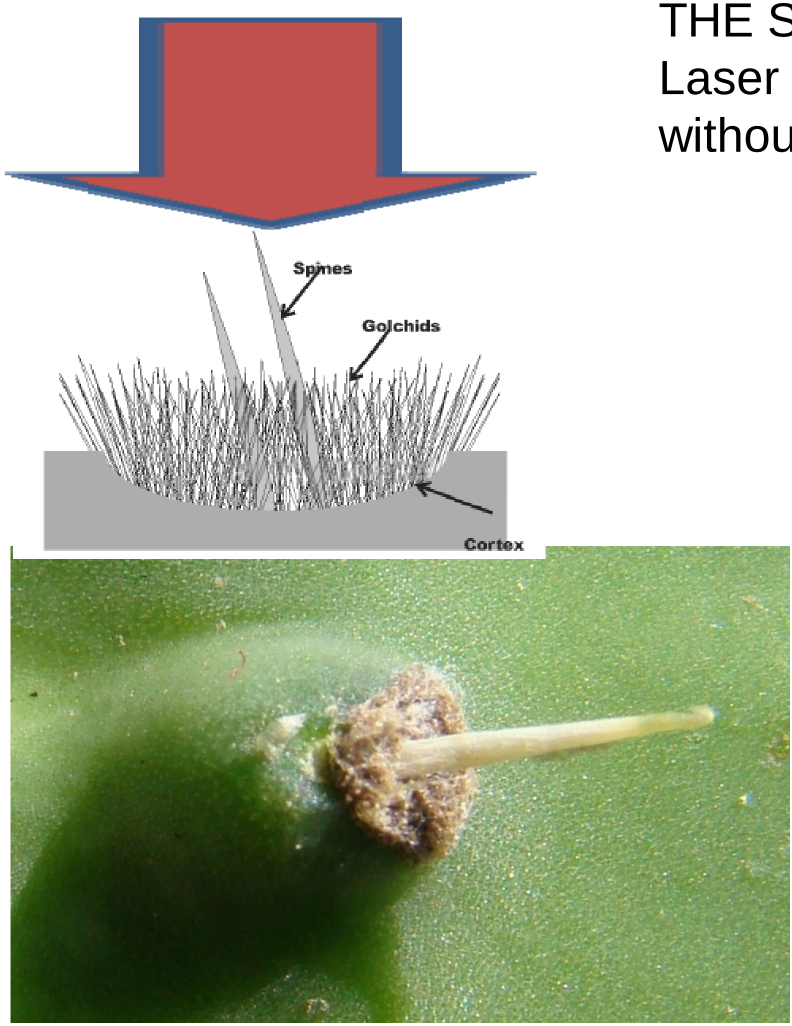
High energy laser pulses can eliminate the thorns without damage to the product?

Using the correct laser parameters (wavelength, pulse energy, pulse duration) the light can be absorbed only by areoles with minimal absorption in other parts

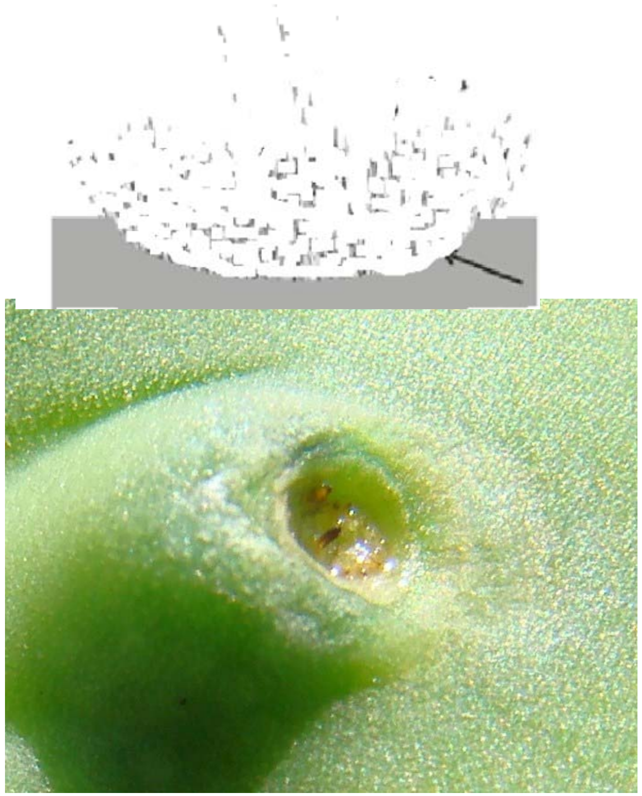


Absorption spectra of Nopal areole and cortex.

Laser beam



THE SOLUTION:
Laser pulses can eliminate the thorns without visible damage to the product

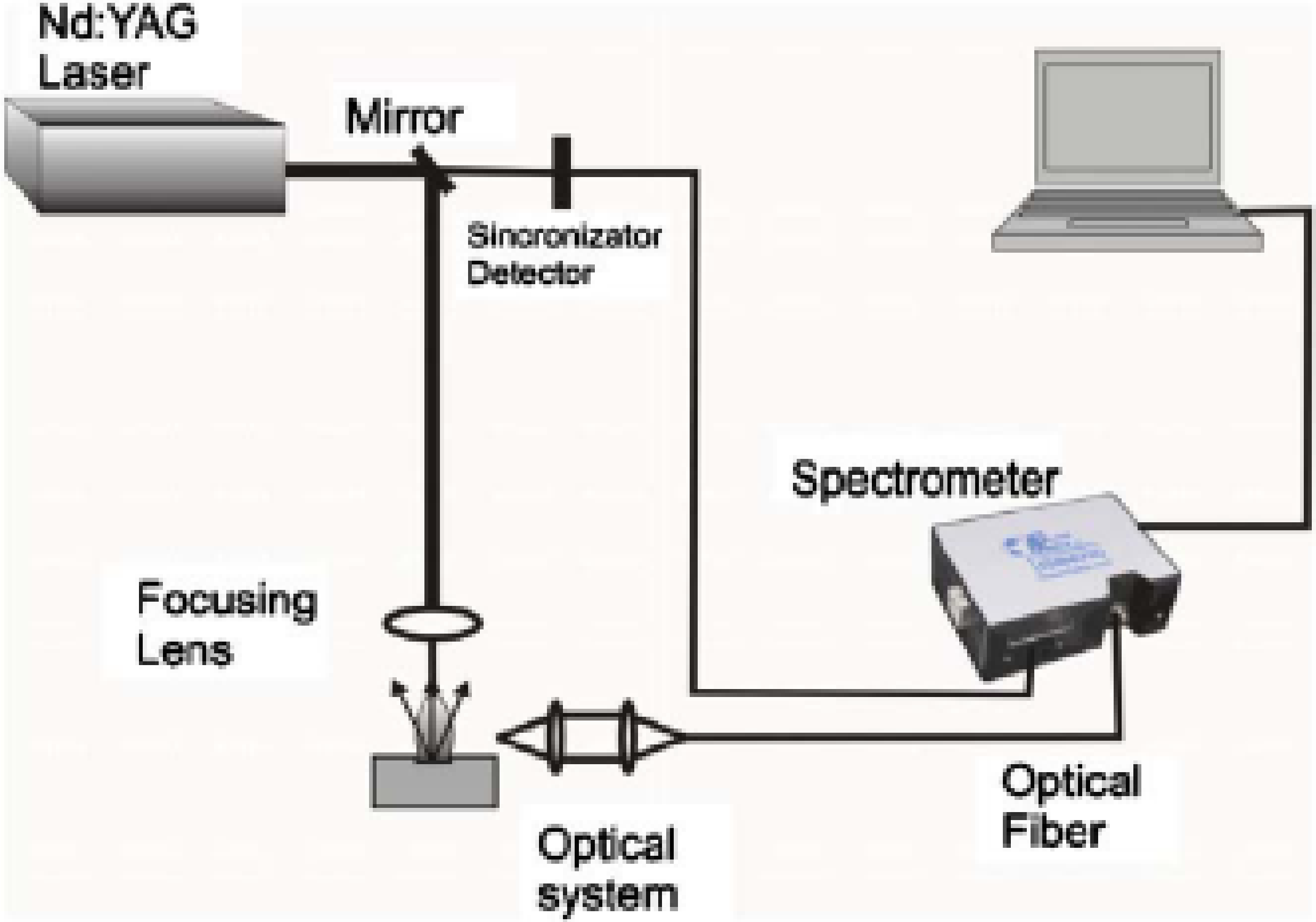


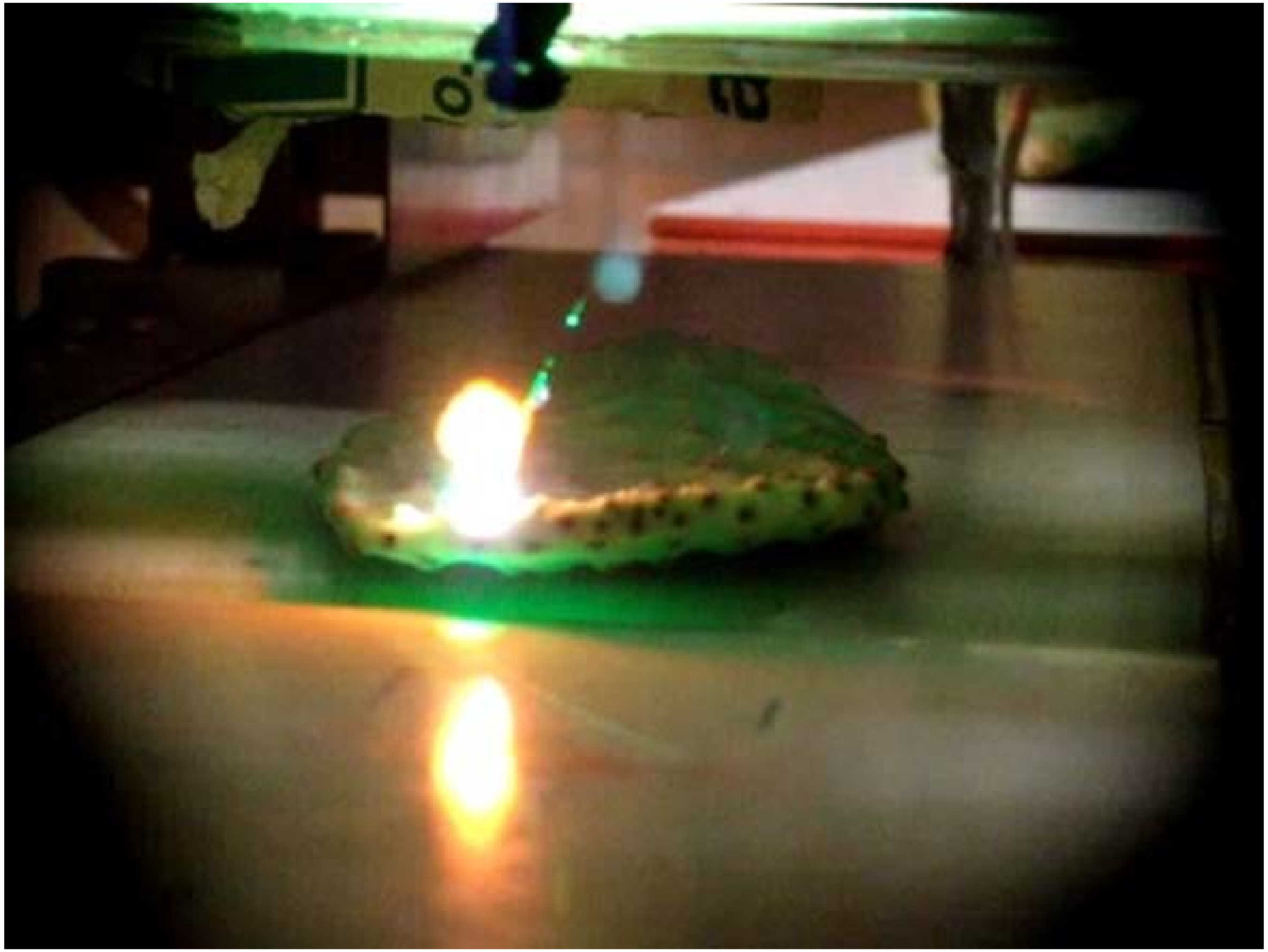
“Laser processing of opunctia family cactus”, L. Ponce, T. Flores, M. Arronte, V. A. Parfenov, L. V. Kovalchuk, L. Bartoli, Journal of Optical Technology, V75, N8, 200

The removal of all spines one to one is a very slow process

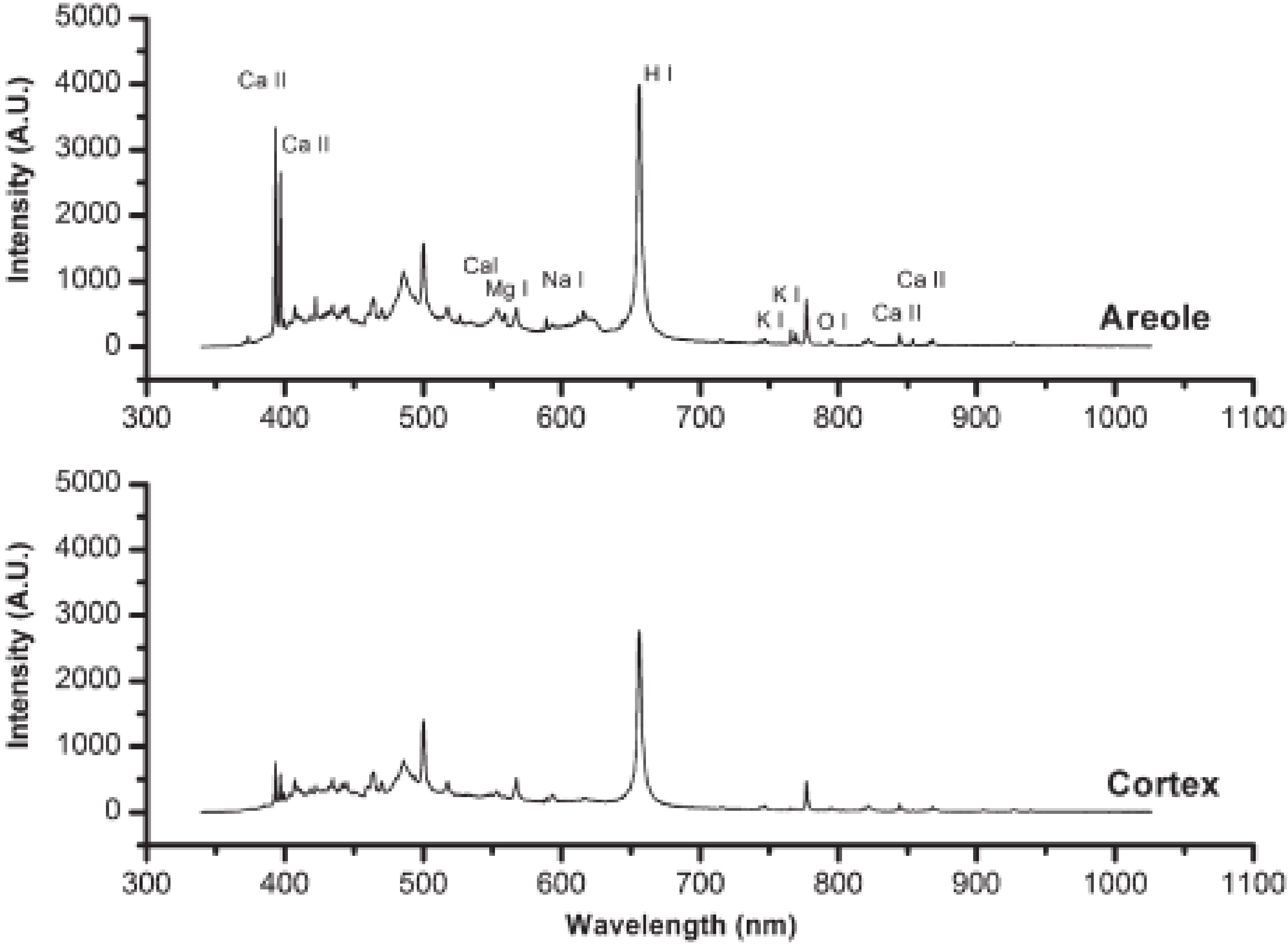
We need a machine

Laser Induced Breakdown Spectroscopy – LIBS experiments



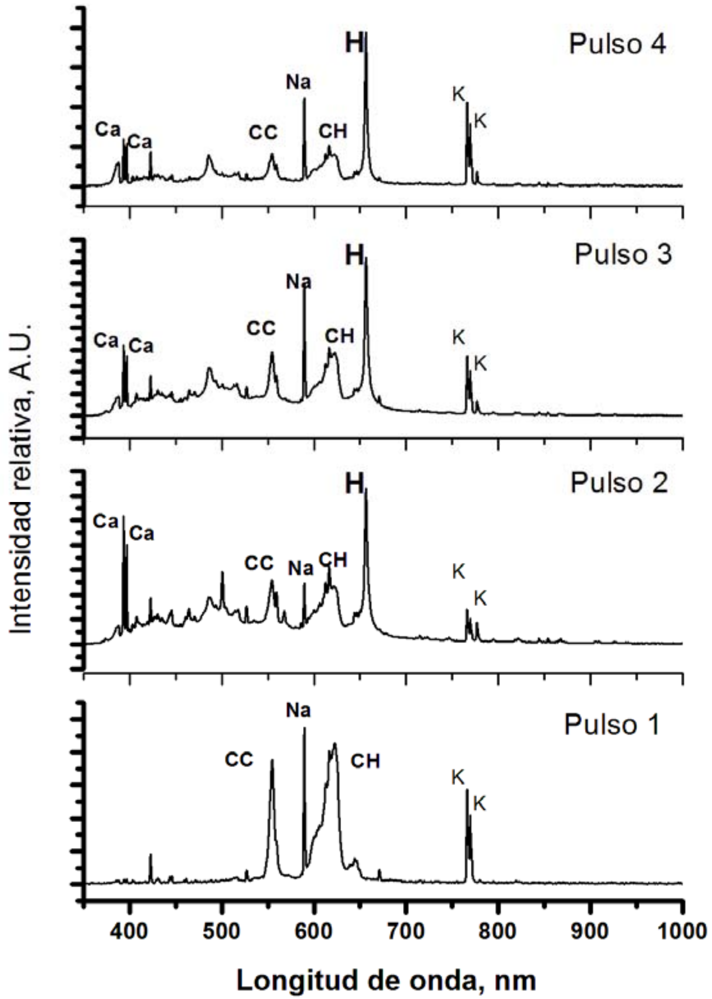


Laser shot on the areole

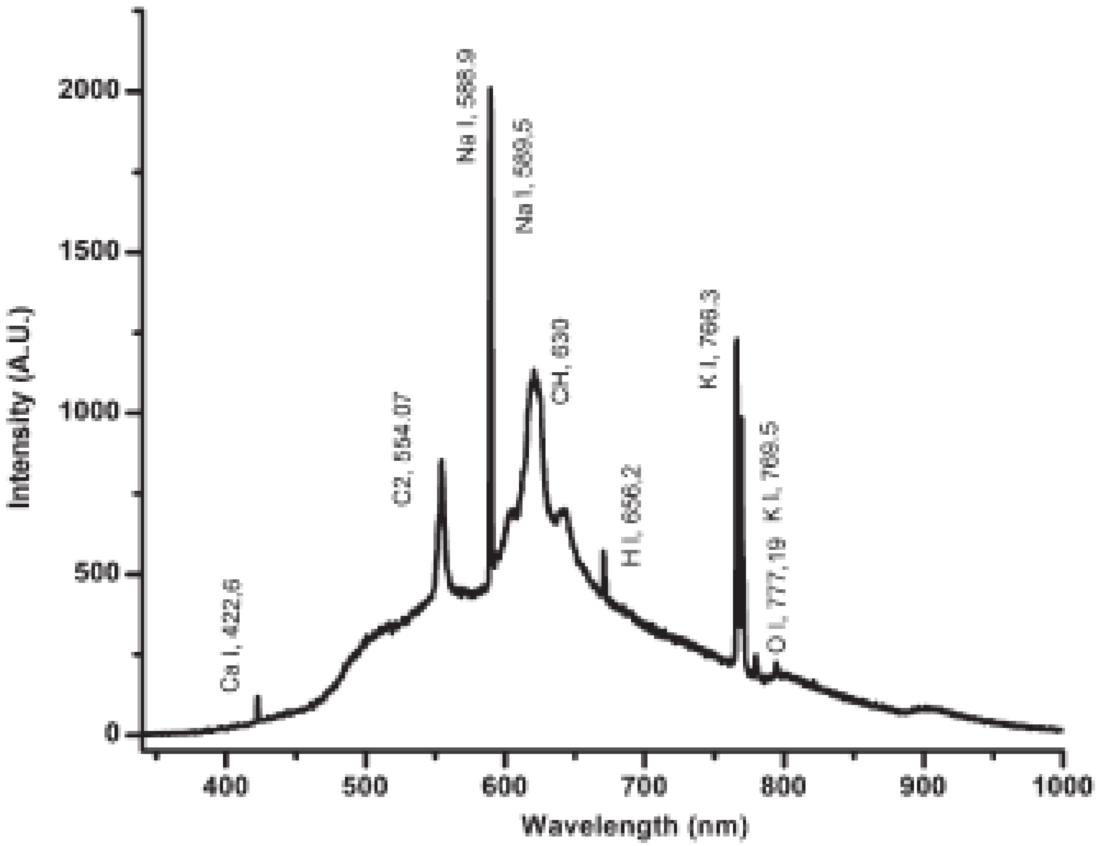


LIBS spectra of the cortex (top) and areole (botton), acquired in ambient atmosphere.

Pulse by pulse LIBS measurement

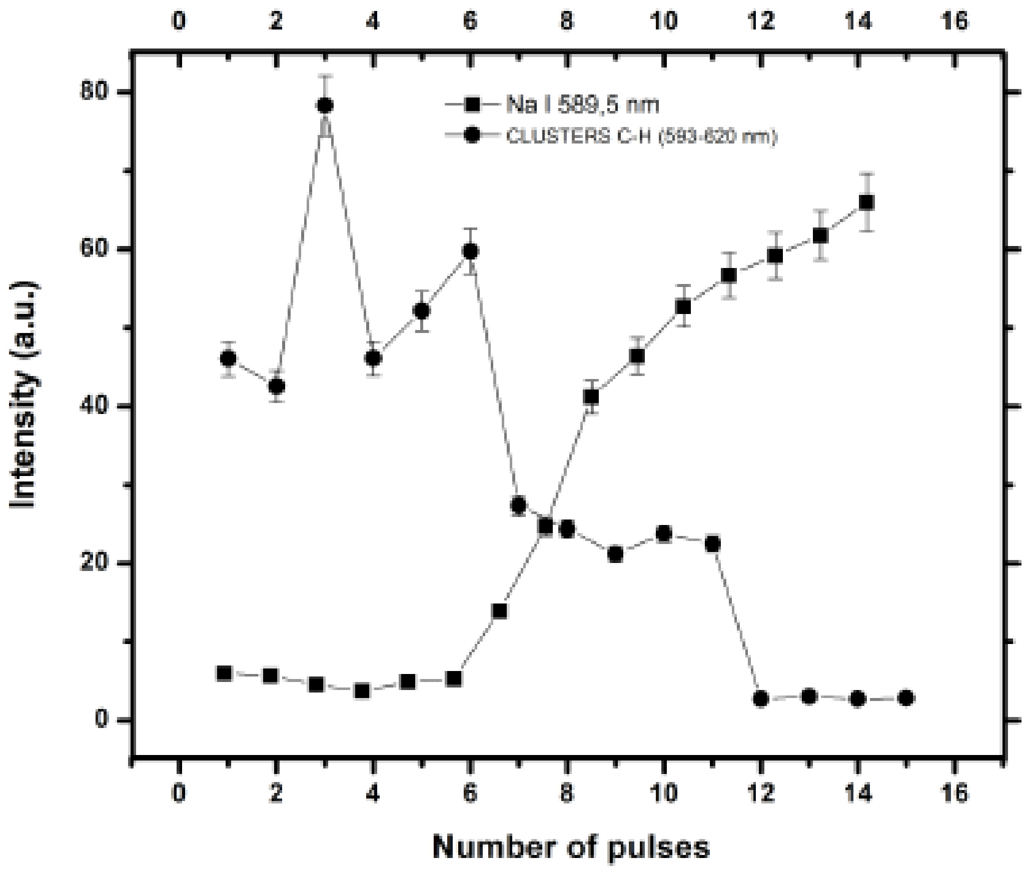


LIBS spectrum in areole using a free-running laser!



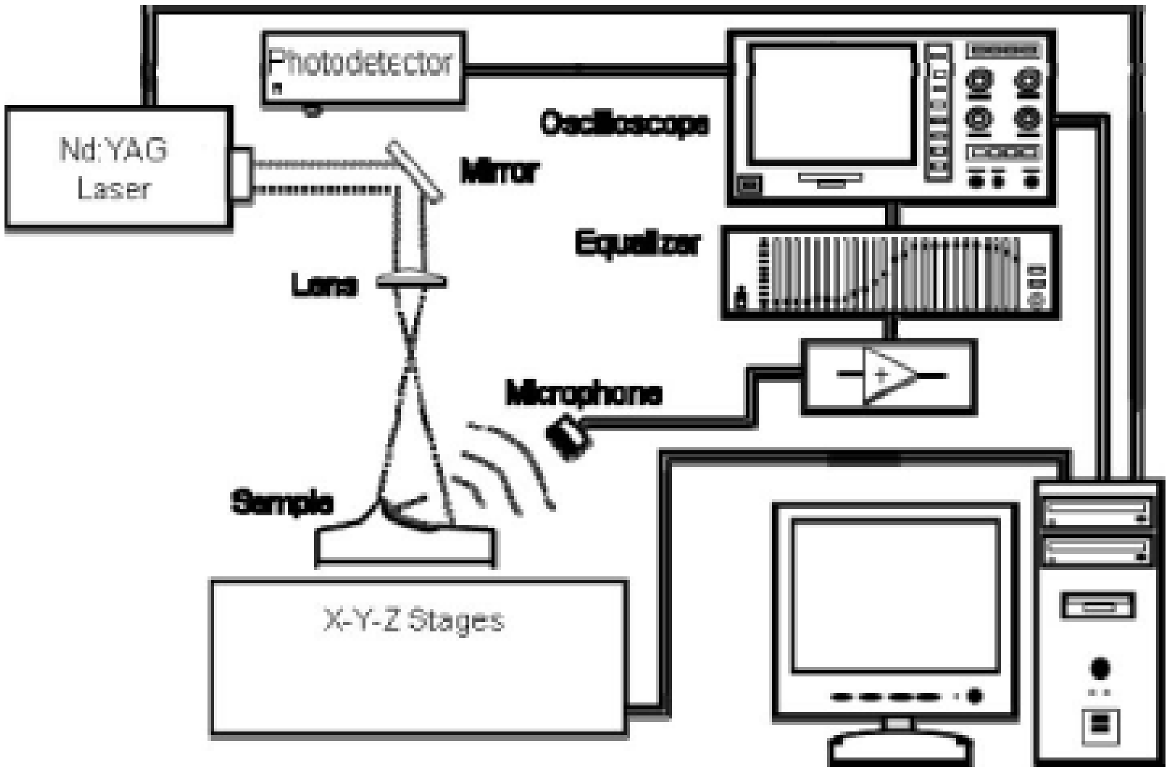
“Free-running and Q:Switched LIBS Measurements During the Laser Ablation of Prickle Pears Spines”, T. Flores, L. Ponce, M. Arronte, E. de Posada, Optics and Lasers in Engineering, 47, 5, 2009

Monitoring the thorns removal process by LIBS

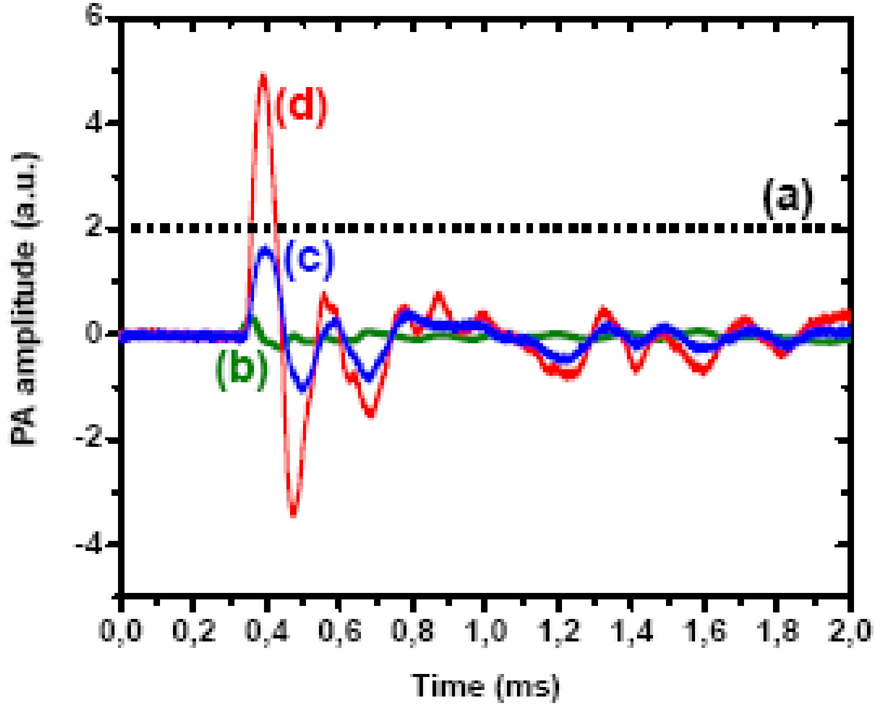


Depth profiling by LIBS

Photoacoustics Induced by Laser Ablation (PILA) experiments

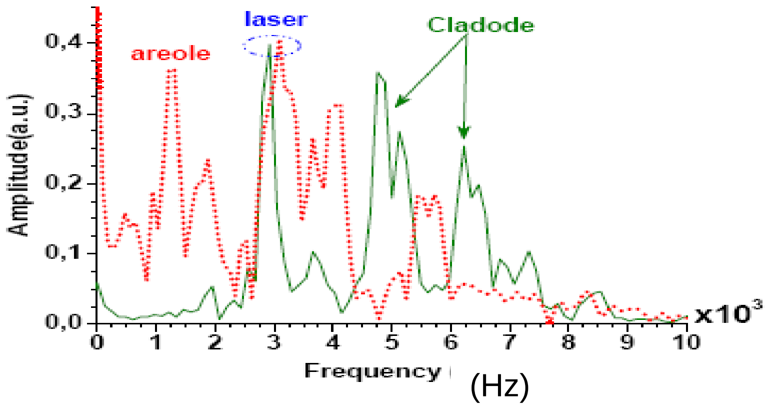


Photoacoustics Induced by Laser Ablation (PILA) experiments



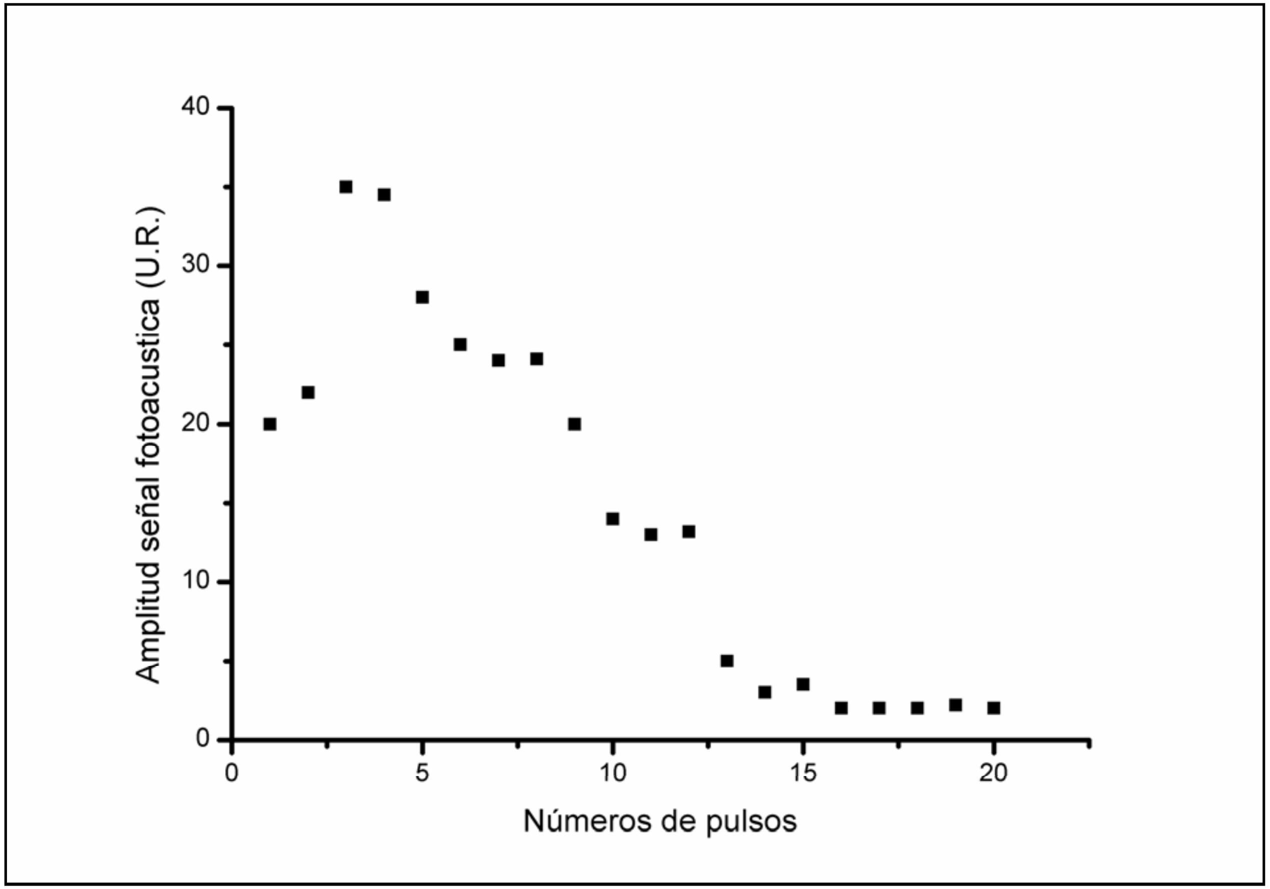
Comparison of the PILA signals. a) Cleanliness reference level; b) PILA signal from the cortex; c) PILA signal generated by pulse 7 in the areola; and d) PILA signal generated by pulse 1 in the areola

FFT acoustic spectrum analysis



FFT spectra of the photo acoustic signal generated by both the areole with thorns (solid line) and the cladode cortex (dot line), after irradiation

- The band of 2600–3400 Hz is associated to the incidence of the laser pulse, because it is detected when it imping on any surface.
- The frequency bands observed from 4500–5500 Hz and from 6000–7000 correspond to the cactus cortex vibrations.
- Frequency bands from 300 Hz to 2200 Hz correspond to the pressure wave generated in the areola during laser ablation

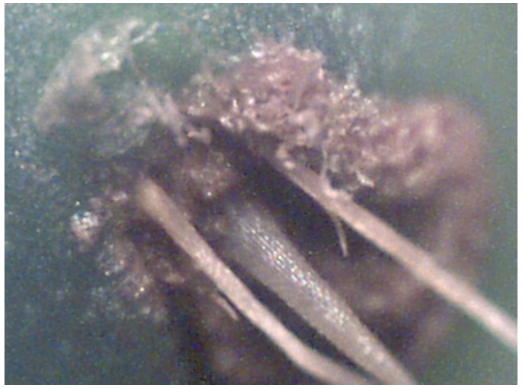


Dependence of the acoustic signal intensity versus the number of pulses for a pulse energy E=900 mJ.

The process pulse by pulse

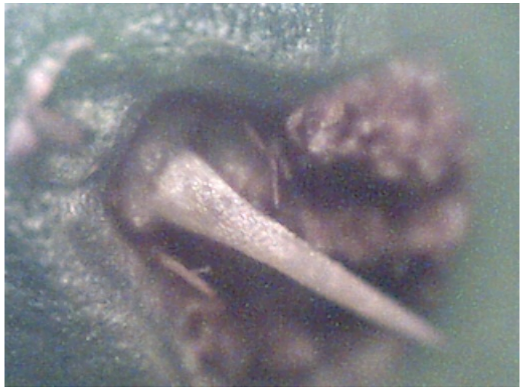
pulse 1

pulse 2



pulse 3

pulse 4

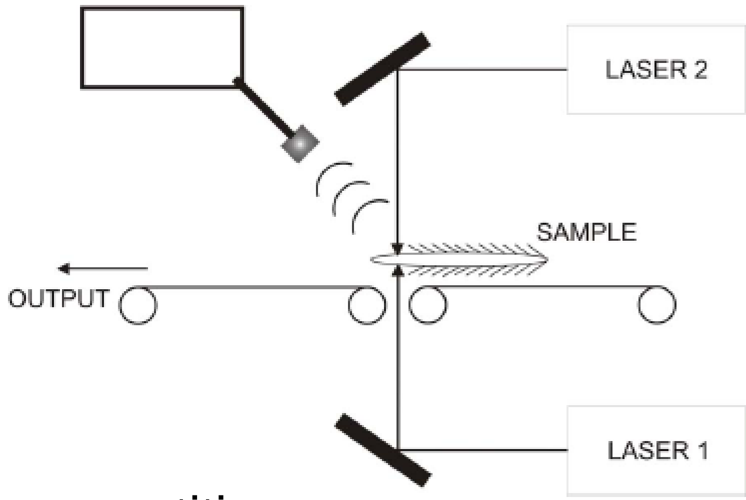


pulse 5

pulse 6

Nd:YAG laser, 1064 nm, 240 μs, 100 pps

The technology of laser machine for thorns removal



The laser beam raster all area of cactus cortex in order to “find” the spines by using photo-acoustic sensor.

Pulse by pulse the spines are eliminated by laser light. The laser pulse repetition rate is 100 Hz.

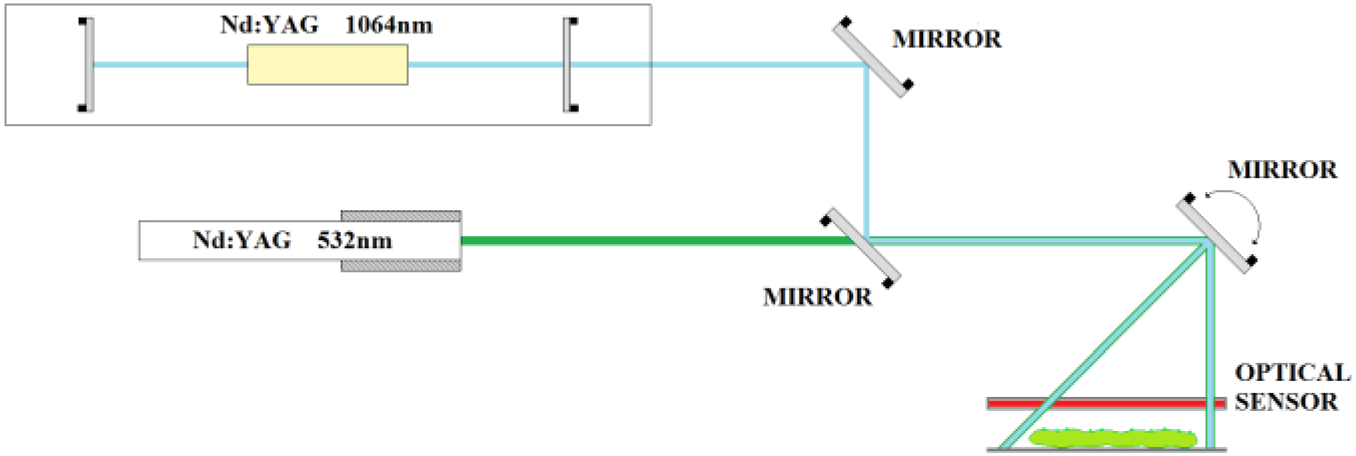
After one thorn is eliminated, the laser continue his work until the cleaning of all surface is completed.

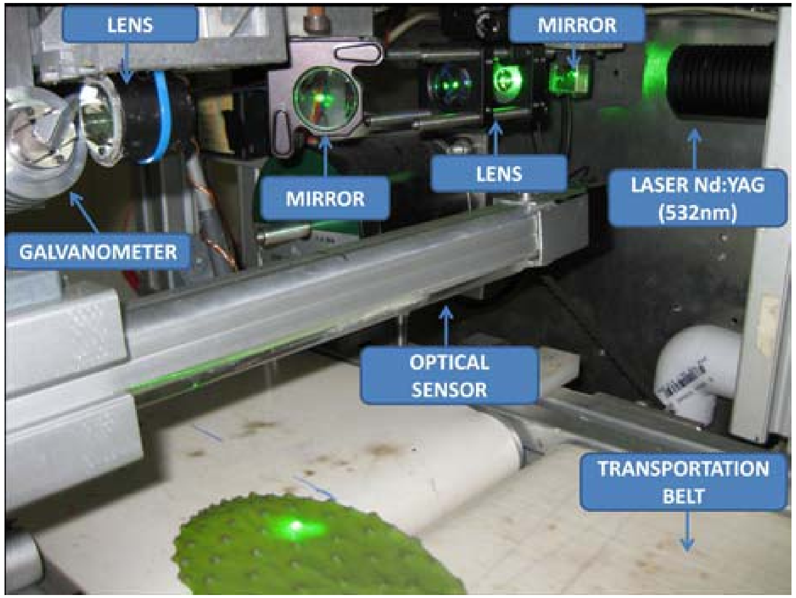
Each cactus is cleaned in almost 60 seconds (20-25 kg per hour). VERY LOW PRODUCTIVITY

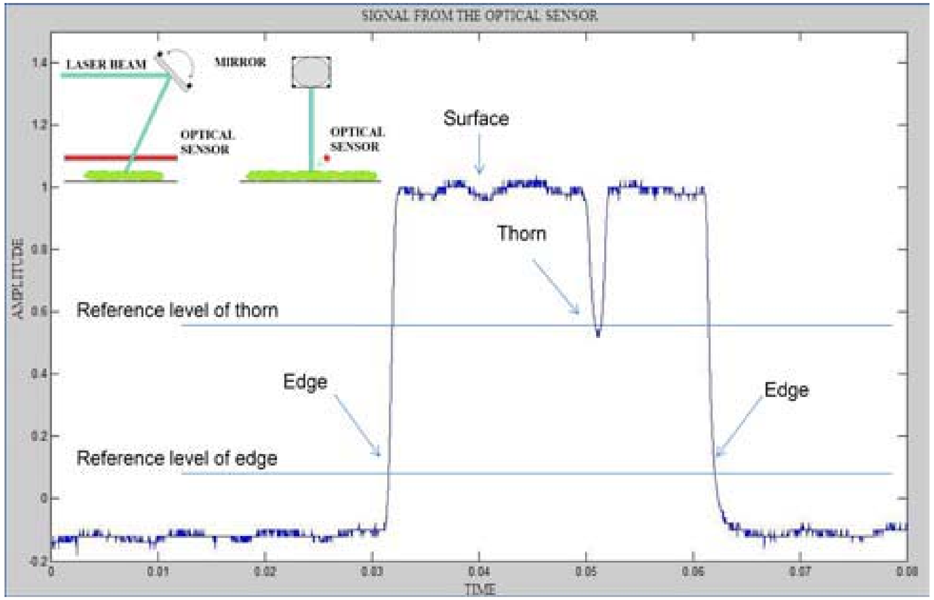
- The photo-acoustic detection works well but the productivity is very low

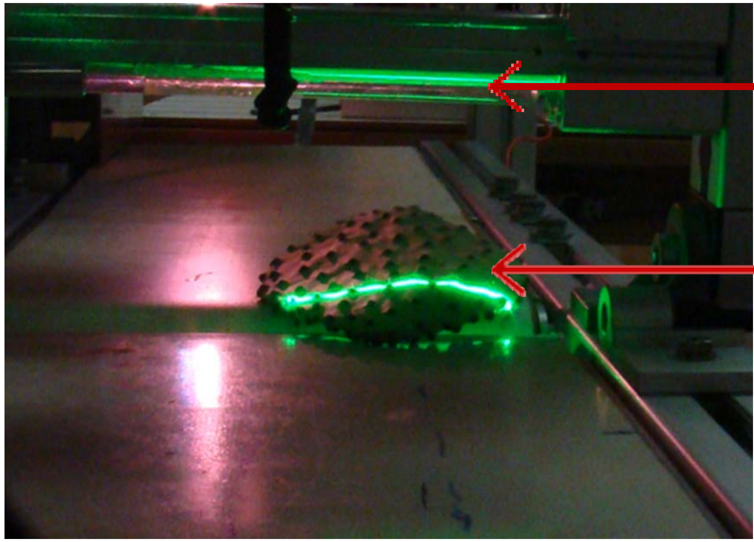
- The solution: Photonic detection

Optical method for detection of spines





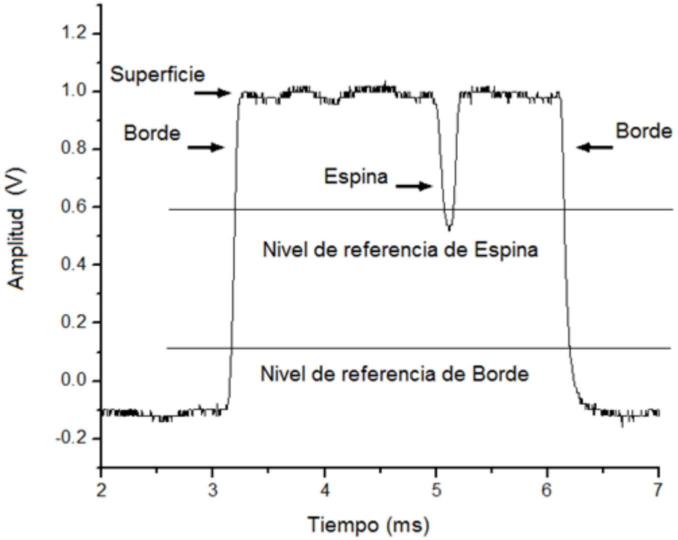




Sensor made using a bundle of fluorescent optical fiber

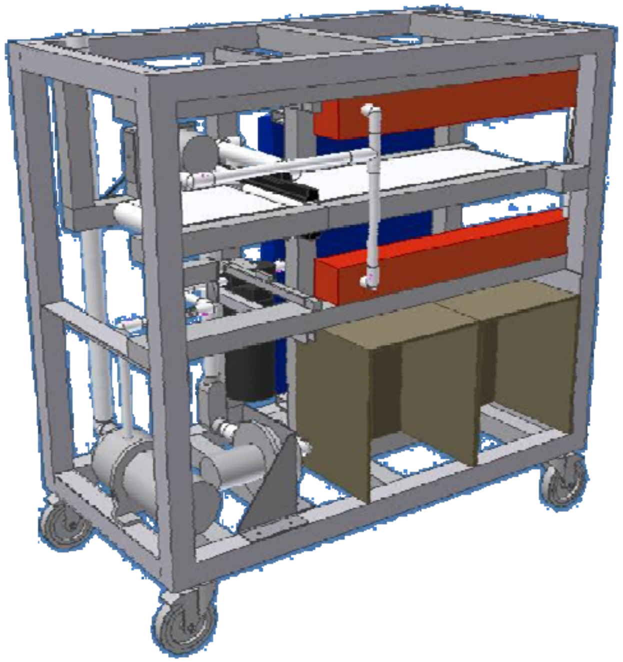
Laser canning of green aiming beam

Direction of displacement



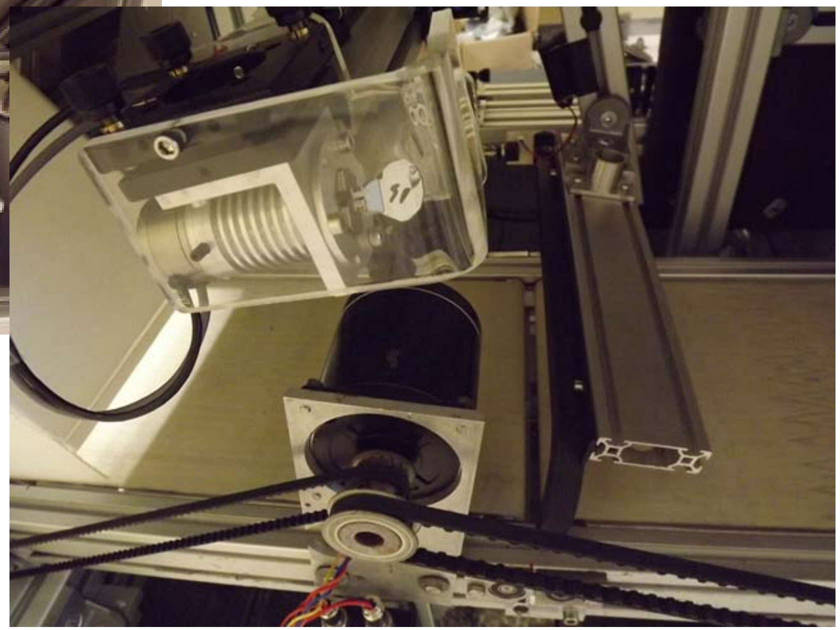
Nopal cladode sample after complete laser removal of thorns

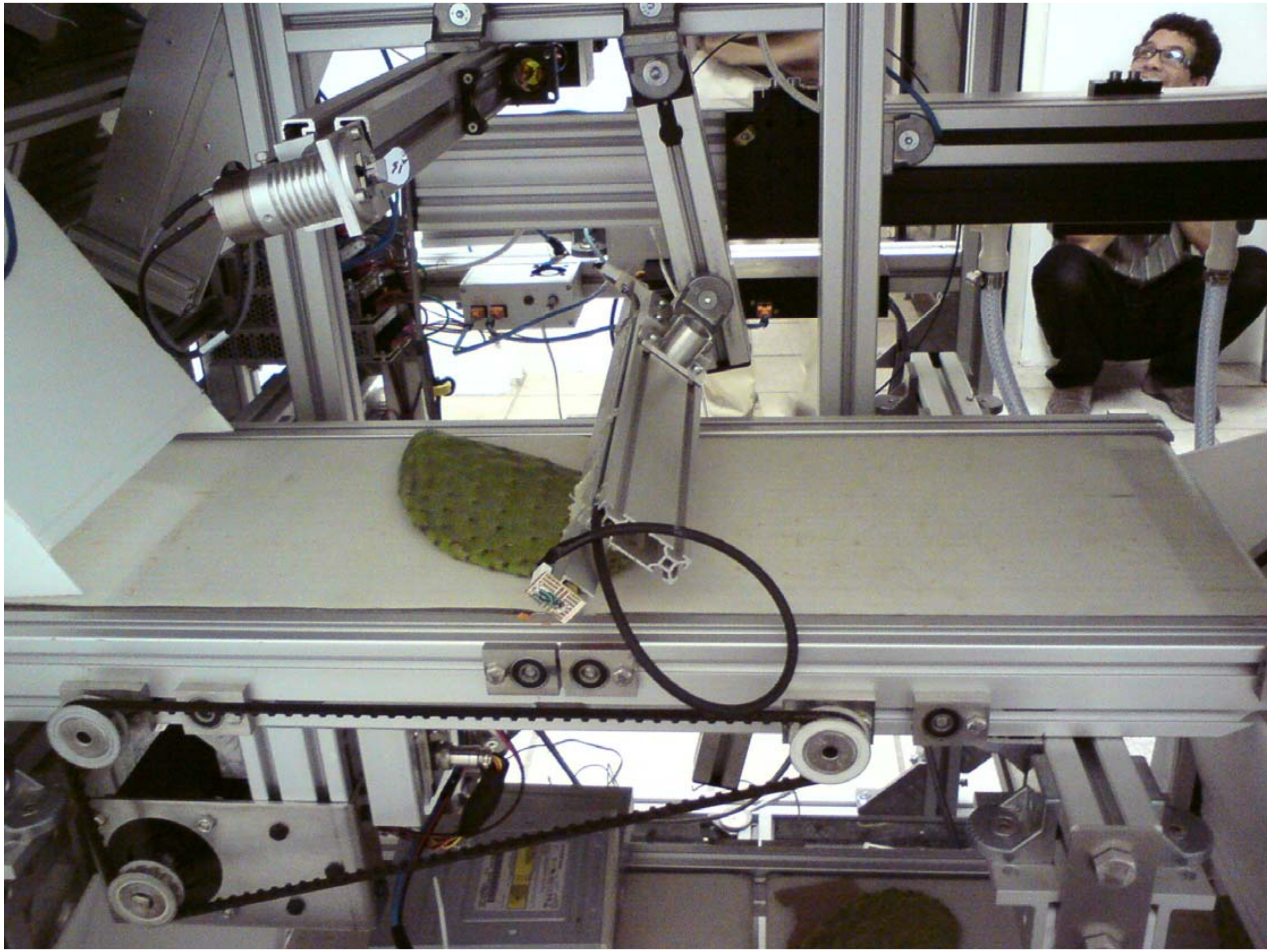
The prototype



PATENTS

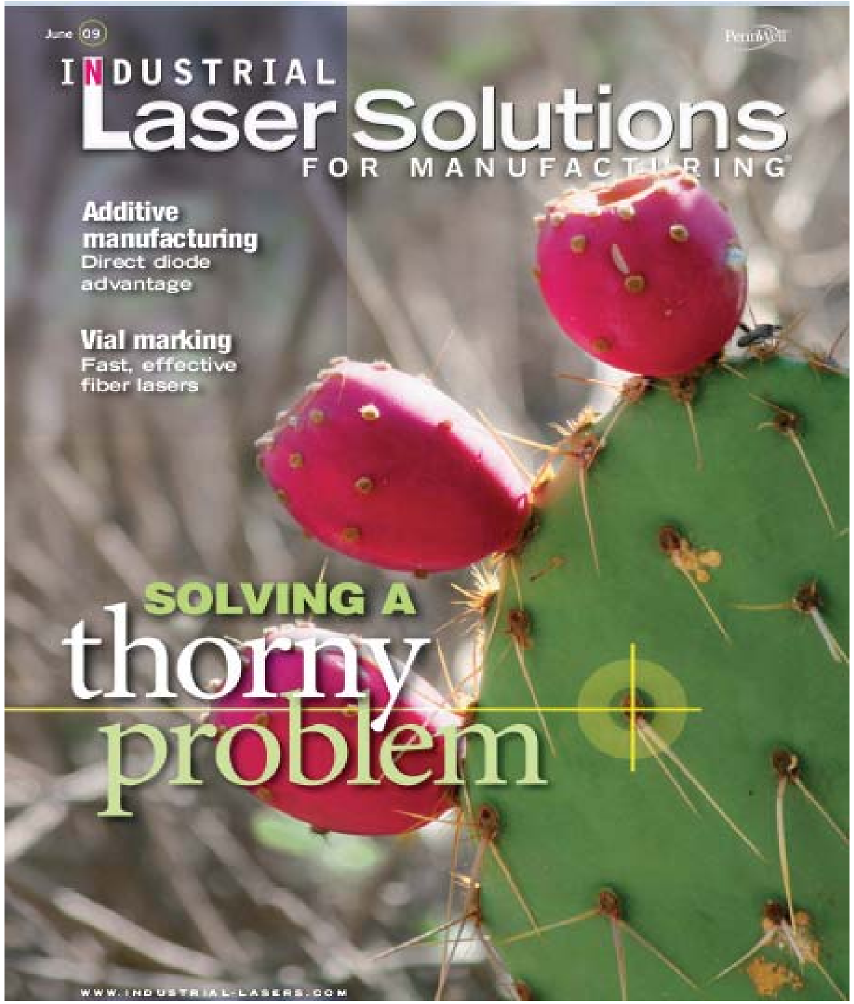
- "Machine for opuntia cactus laser de-thorning", Mexico, patent pending
- "Optic system for control and monitoring of laser de-thorning process of opuntia", international patent pending





Laser parameters

Type of laser	Nd:YAG
Pulse energy	0.8 J
Pulse repetition rate	100 Hz
Pulse duration	200 µs
Spot diameter	4 mm
Electrical power	7 Kw



Email: lponce@ipn.mx

Advantages of laser ablation for thorns removal

- No mechanical damage to the product
- Minimum of waste generation
- Very clean process
- Increase of product life
  (2-3 months after de-thorning)
- Productivity
- It is possible to export the cactus
- Cleaning of other food products?

Mexico demands about 2,000 machines to attend only the cactus de-thorning for export (140 million)

CONCLUSIONS

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International Conference on Optics, Photonics & Photosciences,

October 14-17, 2014, Havana, Cuba

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