Laser **A**ssisted **RO**botic **S**urgery of the anterior **E**ye **S**egment

Project full title:	Laser Assisted Robotic Surgery of the anterior Eye Segment
Project Acronym:	LA-ROSES
Grant Agreement number:	601116
Deliverable no.:	D 3.4
Title:	Test report
Contractual Date of Delivery	month 21
Actual Date of Delivery	11/28/2016
Organization Short Name of Milestone Leading Partner	EKY
Organization Short Name of Other Participants	IFAC, FAST
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Version	1
Tasks contributing to this deliverable	T2
Dissemination Level [1]	RE
Total number of pages (including cover page)	6

[1] Dissemination Level:
PU Public
PP Restricted to other programme participants (including the Commission Services)
RE Restricted to a group specified by the consortium (including the Commission Services)
CO Confidential, only for members of the consortium (including the Commission Services)

Version Management

Version	Date	Status	Author	Modification
1	2/02/2016	Setup	Ekymed	Creation of document
2	10/06/2016	Draft	Ekymed	Structure and initial content
3	10/09/2015	Draft	All partners	Revision/Comments
6	28/11/2016	Final	Ekymed	Final Revision

Summary

1 Executive Summary

The present report D 3.4 aims to describe the LA-ROSES handpiece first tests for the characterization of the 3 motors:

- "x axis", for the horizontal displacement of the laser; equipped with Faulhaber ADM 1220 V6
- "α axis", for the rotation of the laser from 0° - horizontal to 90° - vertical; equipped with Faulhaber ADM 1220 V6
- "ω axis", for the rotation of the laser along the vertical axis; equipped with Faulhaber ADM 1524 V6.

2 Introduction

As reported in the previous reports (D 2.1 in particular) the general scheme of the End-Effector is based on the following functional scheme (see Fig. 1).

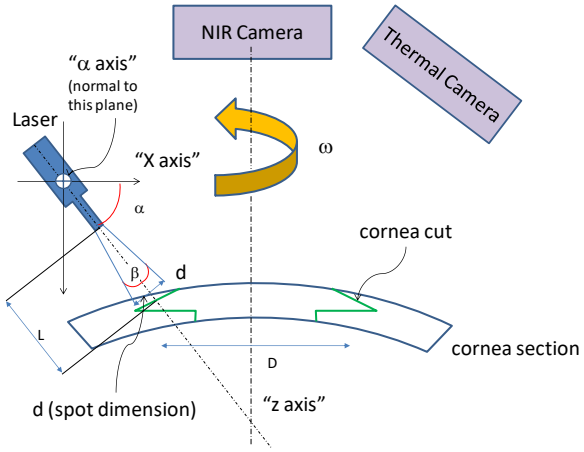

Fig. 1 - General scheme

The next picture shows two the general views (on the left, the first version; on the right the last versions) of the prototype including the 3 motors and the motion control boards MCST 3601.

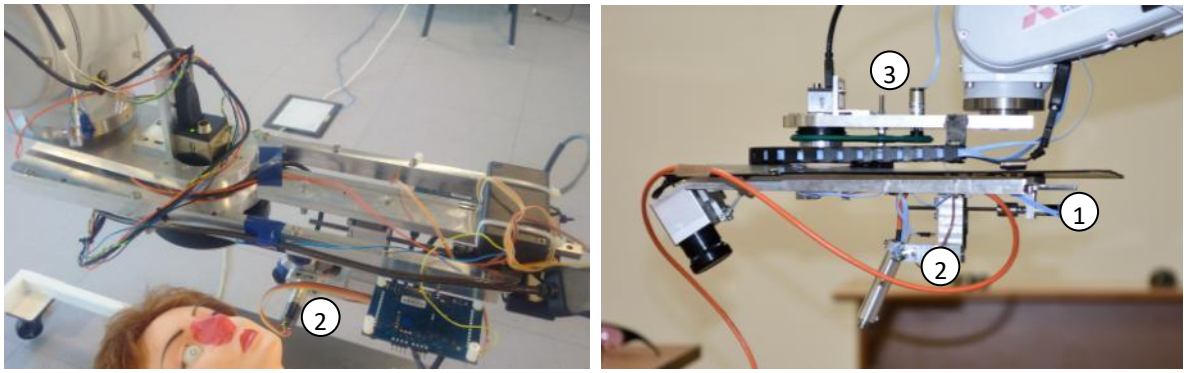

Fig. 2 - End effector close-up

3 "x axis" resolution

The measurement of resolution of the "x axis" (① element of the Fig. 2 right) has been made in this way:

- set-up of the motor parameters through Faulhaber proprietary interface. Microstep set-up on Faulhaber interface: 1/16
- motor displacement of 39 mm (measured proper calibre)
- n. of microstep required: 1.800.000 (media between 12 measurements)

Maximum possible resolution of the "x-axis".

The "x-axis" motor Faulhaber ADM 1220 V6 is equipped with a gearheads 12/5 62,2:1. This means that a single step at the motor (18 °) is directly transformed in 18°/69,2 = 0,26 °. The control board MCST 3601 is able to control the motor in microsteps of 1/256. The final result, in terms of rotation is a minimum angle of 0,26/256 = 0,001°. In terms of equivalent displacement, taking into account that the nut/shaft module is M4 x 0,5, the obtained mechanical resolution for positioning the laser module along the x-axis is 0,001 x 0,5= 0,5 μm.

4 "α axis" resolution

The measurement of resolution of the "α axis", (② element of the Fig. 3) has been made in this way:

- set-up of the motor parameters through Faulhaber proprietary interface. Microstep set-up: 1/64
- motor rotation of 90° (bubble level)
- n. of step required: 206.500 (media between 8 measurements)

Maximum possible resolution of the "α axis".

The laser bending motor Faulhaber ADM 1220 V6 is equipped with a gearheads 12/5 161:1. This means that a single step at the motor (18 °) is directly transformed in 18°/161 = 0,11 °. The final result, in terms of rotation is a minimum angle of 0,11/256 = 0,0004°. In this case considering the next picture, we can transform a minimum rotation of 0,0004° in a displacement "l" in this way: $\frac{0.0004\pi}{180} 100 = 0{,}7\ \pi\text{m}$

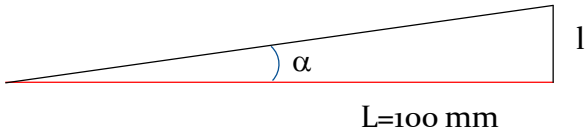

Fig. 3 - Displacement on the cornea

5 "ω axis" resolution

For this The measurement of resolution of the "ω axis", (③ element of the Fig. 3) has been made in this way:

- set-up of the motor parameters through Faulhaber proprietary interface. Microstep set-up: 1/8
- motor rotation of 360°
- n. of step required: 300.100 (media between 10 measurements)

Maximum possible resolution of the "ω axis".

The laser bending motor Faulhaber ADM 1524 V6 is equipped with a gearheads 15/8-1670:1. This means that a single step at the motor (18 °) is directly transformed in 18°/1670 = 0,01 °. The final result, in terms of rotation, is a theoretical minimum angle of 0,01/256 = 4,2 E^{-5} °.

All Faulhaber motors have proven reliable, after hours of work, with the exception of RDM66200 substituted by the Faulhaber ADM 1524 V6.

6 Laser handling control unit first movement tests

The laser movement control under development here described is devoted to provide movement control capabilities to the laser tip only: i.e. circular, translational and orientation movements. The FAULHABER motor previously described are driven by 3 identical servo controller; to simplify the motor control all selected motors are driven by the same type of control unit suggested by FAULHABER. The MCST 3601 is the chosen motor electronic driver. Following instruction of FAULHABER we realized a electrical and communication connection diagram as to be able to control all laser handling motors by using a USB 2.0 HUB. Fig. 4 shows the connection driver diagram.

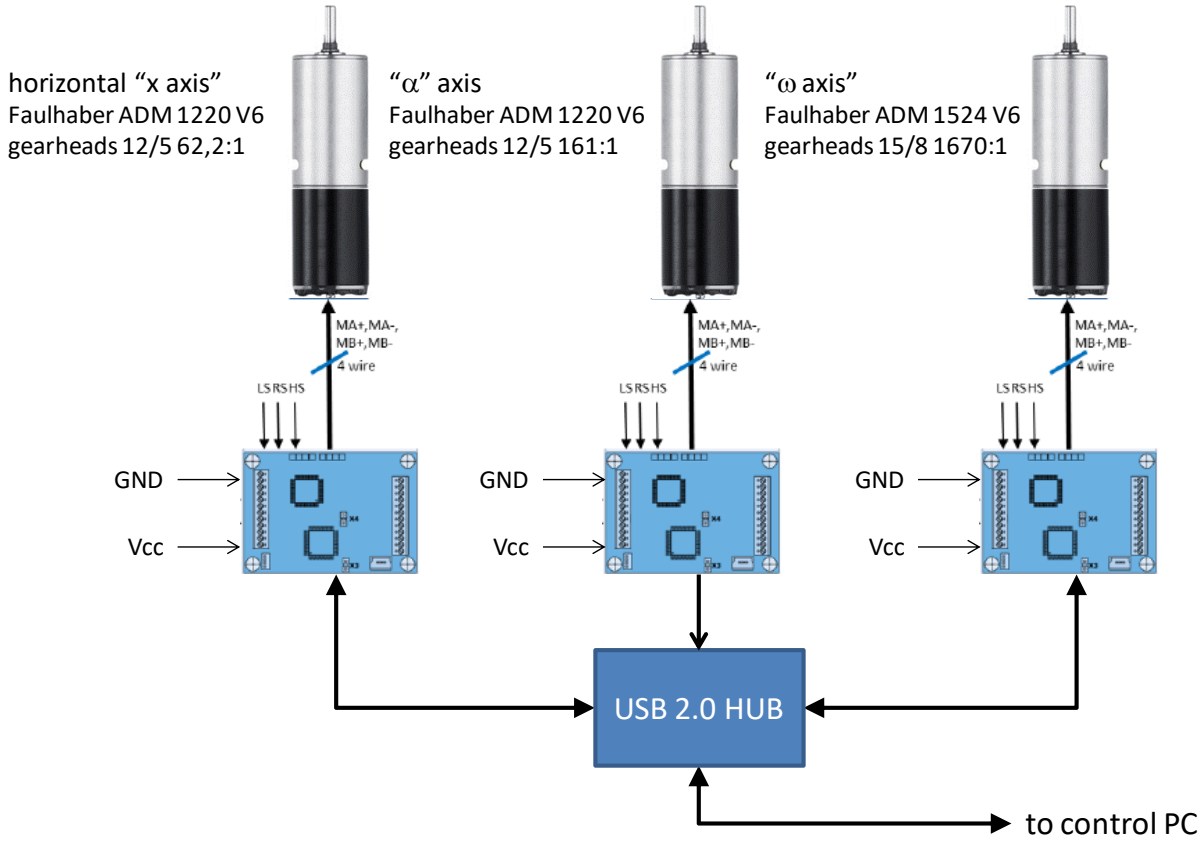

Fig. 4 - connection diagram to control LA-ROSES end-effectors motors

To interact with motor drivers and for setting motion motor parameter Faulhaber provides an Integrated Development Environment (IDE) called TMC. In Fig. 5 the TMC interface is shown

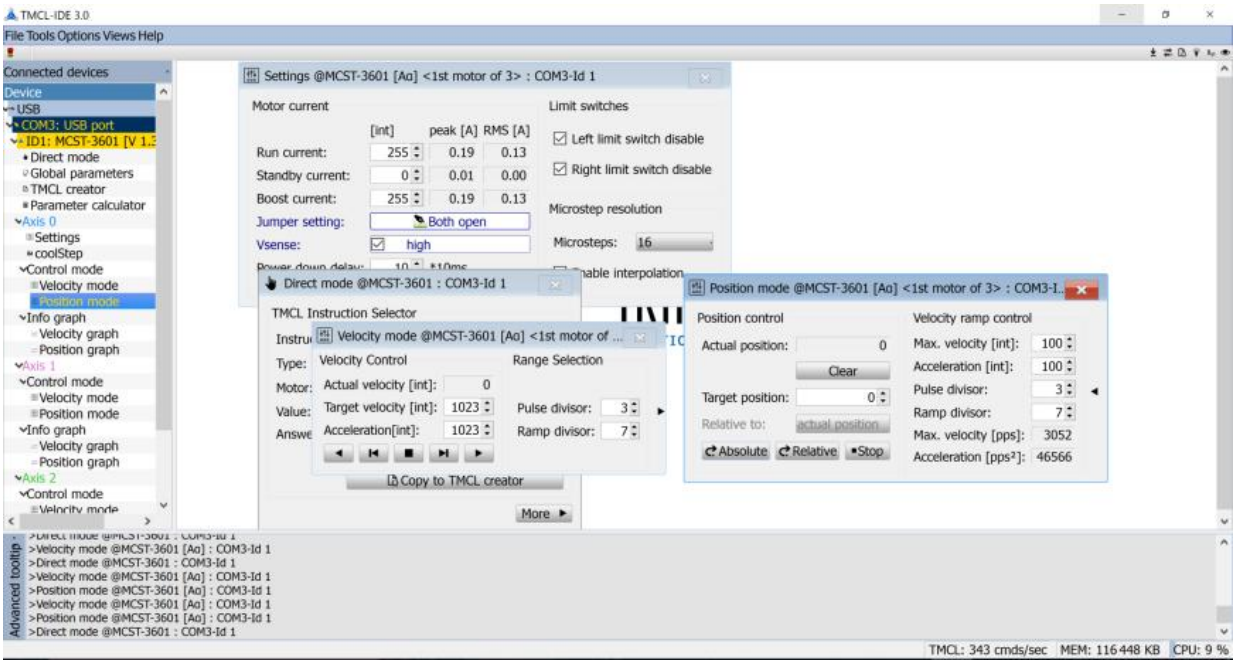

Fig. 5 - Faulhaber IDE for setting motor's motion parameters for laser movement

The interface allows to set acceleration and velocity profiles that the internal PID controller will use to appropriately control the motor actuation. Once the motor parameters were settled the interface allows also to send position and velocity commands in order to evaluate if the motion result is as expected. We found that the chosen motors and drivers were able to achieve the expected resolution movement provided by the mechanical system. In particular the movement forward and reward between the home position of the final position of each axis shows high repeatability in terms of value of position counter reached at each trial.