D5.5

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Author: TUW

Provide demonstrator with 120x75x100 mm³ build volume and 15 µm resolution

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Project coordinator:	TUW (Technische Universität Wien)
Partners:	(lead) TUW
	(involved) Lithoz
	(involved) In-Vision

Project no. 633192

"Toolless Manufacturing of Complex Structures"

ToMax

FoF-02-2014 "Manufacturing processes for complex structures and geometries with efficient use of material"

D5.5 Provide demonstrator with 120x75x100 mm³ build volume and 15 µm resolution

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Dissemination Level		
PU	Public	x

History chart

Version	Author	Date	Status	Reviewer
1.0	Busetti B.	15.06.2017	draft	
2.0	Busetti B.	01.09.2017	resvision	
			final	21.09.2017

Abstract

This deliverable shows the completion of the 3D-printing demonstrator within the ToMax project. A fully operational 3D-prinitng demonstrator is provided, including a hybrid exposure concept. The targeted feature resolution of 15 µm as well as the building volume of 120x75x100 mm³ could be provided. Additionally the feasibility of the hybrid exposure approach is shown and provides herby a versatile and throughput enhanced machinery.

With this deliverable the WP5 is completed.

Content

Es wurden keine Einträge für das Inhaltsverzeichnis gefunden.

List of abbreviations

AMT … Additive Manufacturing Technologies
CAD … Computer aided design
L-AMT… Lithography based Additive Manufacturing Technologies
WP … Work package
SLA … Stereo-lithography
DLP … Digital Light Processing
LE … Light Engine
CCD … Charge-Coupled Device
CMOS… Complementary Metal-Oxide-Semiconductor
TUW … Technische Universität Wien

1. Introduction

This document provides a final report and overview of Work Package 5 (WP5). In the grant agreement of the ToMax project, the following objectives were defined:

- Develop lithography based 3D-printer with high resolution and large build volume
- Equip 3D-printer with capability for processing of high-viscosity resins
- Provide data for life cycle assessment
- Develop process for wash-away support structures

The previous deliverables "D5.1 - Provide system specifications" [1], "D5.2 – Provide heated vat for high viscosity resins" [2], "D5.3 – Provide a L-AMT system with first generation Light Engine" [3] and "D5.4 – Provide L-AMT system with integrated second generation light engine" [4] show the approach, starting from the design leading to the assembly and final test of the machinery. All objectives could be provided and a feasibility of the hybrid exposure approach is shown.

2. Technical Approach and result

The main goal was to provide a L-AMT-system, which includes a hybrid exposure concept. Figure 1 shows the final assembled 3D-printing machinery of the ToMax Project. The final dimension of the setup is 800x600x1800 mm³ (WxDxH). The housing is a commercially available control cabinet painted in matt black.

Figure 1:Fully assembled AMT-system at TU Wien

Table 1 shows the breakdown of the 3D-printing machinery. All modules are provided in order to allow the production of unfilled and filled materials (eg. Polymers or ceramics). The laser system and the DLP LE can be used separately or in combination. This hybrid exposure concept combines the benefits of both light sources in order to enhance the throughput and the feature resolution.

Table 1: Modules of ToMax L-AMT system

Module	Title	Subdivision
MD 1	General framework	Internal framework
		Housing
		Backbone
MD 2	Building platform	Material vat
		Tilting mechanism
		Recoating mechanism
		Building platform
MD 3	Optical Module	Laser-system
		DLP Light engine
		Calibration-system/Online monitoring-system
MD 4	Electronics	Motors
		I/O devices
		Energy supplies
MD 5	Software	PLC
		Laser control
		DLP control

2. AMT demonstrator

The core element within the AMT-system is the optical unit, which facilitates the light source combination and finally enables the hybrid exposure concept. The project partner Lithoz supported the development with expertise in software development and mechatronics and In-Vision provided the design and hardware for optical components like DLP LE and a dichroic beam splitter for the beam-alignment. Together with both project partners, we could provide the ToMax AMT-system, which comprises all requirements of the ToMax-grant agreement. The desired building volume was 120x75x100 mm^3. The second generation DLP LE contains a WQXGADMD chip, which leads with a pixel size of 56 µm to a final building envelope of 144x90 mm². The laser-scanner is able to cover a typical area of 140x140 mm². Thus, the claimed building volume could be exceeded.

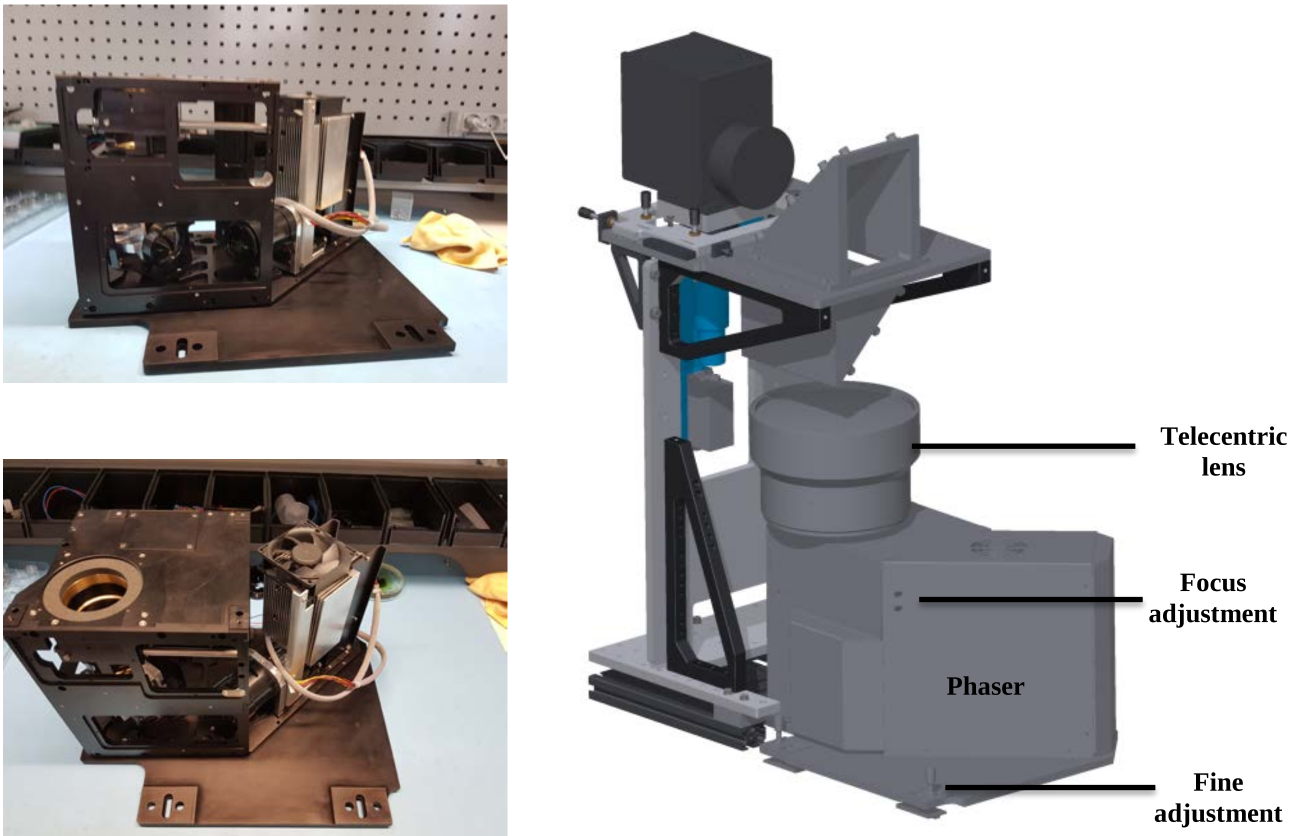


Figure 2: Assembly and Design of the second generation DLP LE with telocentric optic

The desired resolution in this deliverable is 15 µm. The laser spot-size is determined by the combination of optical hardware components. The main components are the beam expander in front of the laser-scanner and the focusing f-theta lens. For our purposes a laser scanner IntelliScan14$_{SE}$ (Scanlabs), with a focal length of f = 250 mm and an f-theta lens was chosen. With a beam-expansion of 10 mm a laser spot diameter of d_s = 18 µm can be calculated. This theoretical value can increase due to optical errors like misalignment or astigmatism effects. After a final calibration the measured spot diameter is d_s = 20 µm. Figure 2 (a) shows the measurement of the laser-spot size. If a several laser lines are applied in a hatching distance of h_s = 20 µm next to each other an energy distribution like in Figure 2 (b) can be obtained. Figure 2 (c) shows the hatch pattern of a fully cured structure. In this case the hatch is applied in 0° and 90° and the hatching distance is h_s = 20 µm. The obtained pattern corresponds to the energy distribution of Figure 2 (c) and hereby the laser spot measurement is proved.

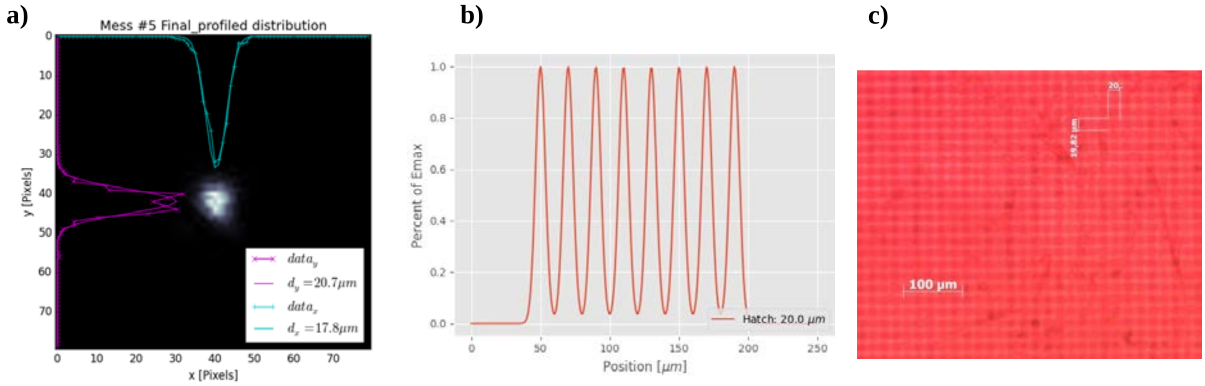


Figure 3: (a) Characterization of the laser-spot diameter (b) Energy distribution at a hatch distance hs = 20 µm (c) Hatch pattern at hs = 20 µm at 0° and 90°

However, the final feature resolution is determined by the combination of hardware settings (E.g. Laser speed and –power) and the reactivity of photosensitive material. Figure 4 shows a single line of polymer, cured by the laser. In this case a linewidth of l_w = 5.92 µm could be obtained. Although the laser spot size is larger than 15 µm a higher resolution is possible. Thus the claimed resolution of 15 µm is provided and the deliverable is fulfilled.

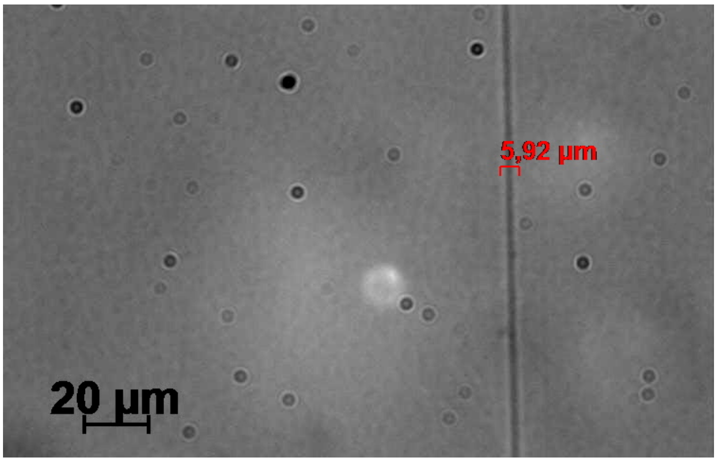


Figure 4: Single laser exposed line

The system allows a rapid and efficient production of small-scale series due to the large building volume of 144x90x150 mm³. Figure 5 shows some examples of printed structures. In Figure 5 (a) a model of the Eiffel tower is shown (height: 101.7 mm). Figure 5 (b) shows the model immediately after printing inside the AMT-system. In a collaboration with project partner UPM, some designs where provided. Figure 5 (c) shows the printed shell of a modified BIC pen. The design is provided UPM. Figure 5 (d) shows 160 piece of ball bearing cages, exploiting completely the building envelope (144x90 mm²).

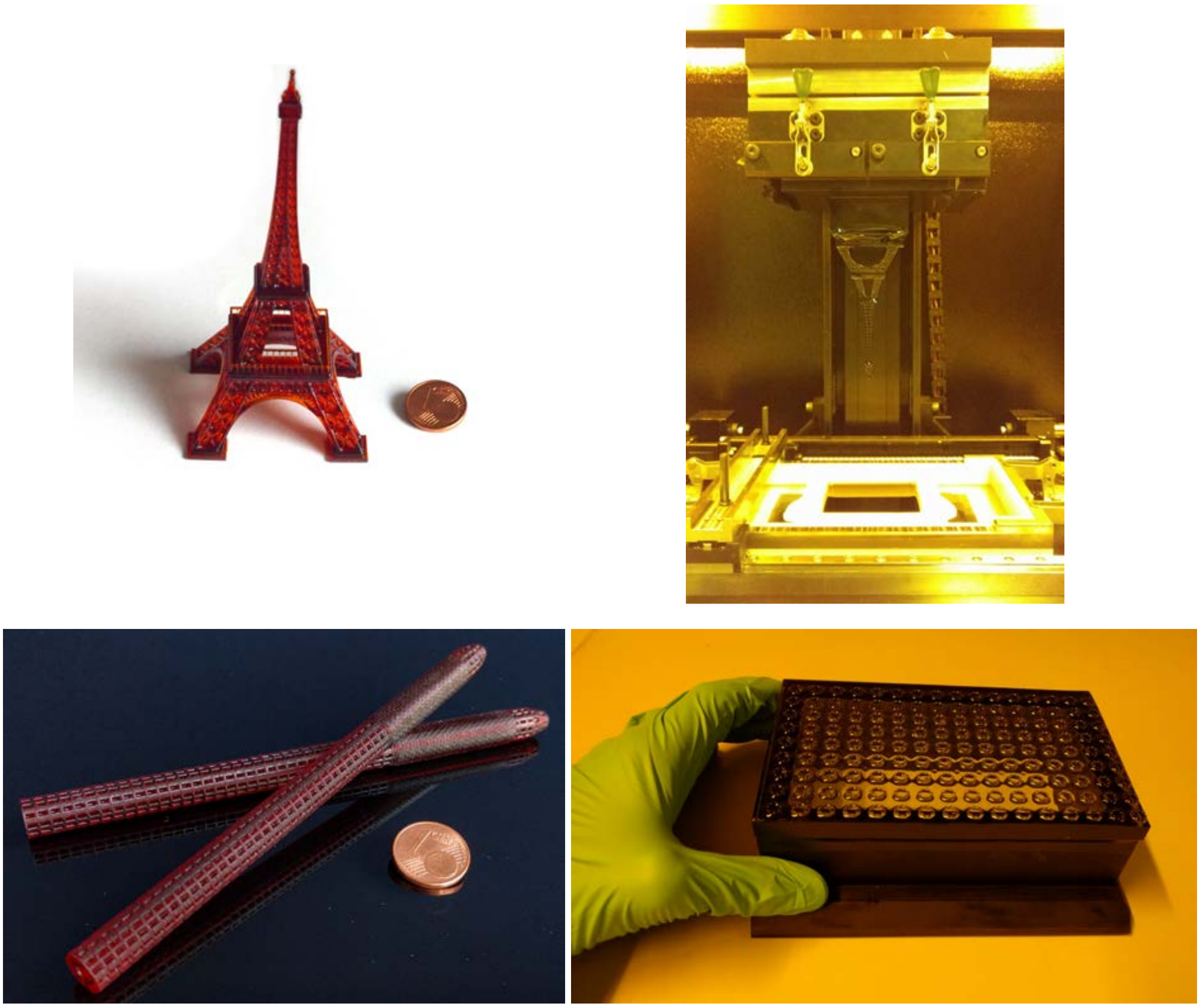


Figure 5: Example of 3D-printed structures

2.2. Key facts of the ToMax L-AMT system with second generation DLP LE

- **Second generation DLP LE:**
  - Wavelength 450 nm
  - WQXGA DMD-chip (2560x1600 Pixels)
  - Pixel size 56 µm
  - Field size 144x90 mm^2
  - >95% uniformity of intensity
- **Laser:**
  - Wavelength 405 nm

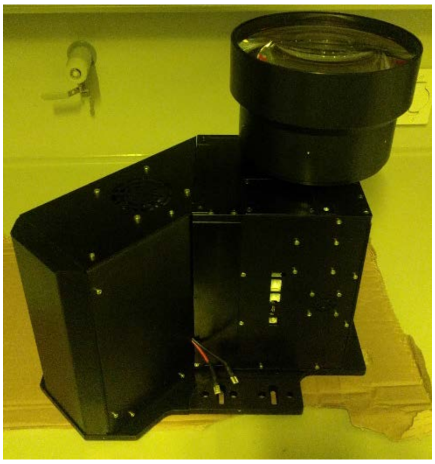
- Laser power max. 300 mW
- Calculated laser-spot diameter 18 µm
- Measured laser-spot diameter 20 µm
- M^2= 1,01

- **Laser-scanner:**
  - Position resolution 20 bit (0.18 µm)
  - Repeatability (RMS): 0.1 µm
  - Max. mark speed 2 m/s
  - Max. jump speed 5 m/s
  - Typical field size 140x140 mm²
  - Pixel frequency 300 kHz

2.3.Conclusion

This deliverable demonstrates that we provided a fully operational AMT-system, which contains two different light sources. The modular designing approach enabled a systematic work and step-by-step a hybrid exposure-concept could be realized. Figure 6a shows the final assembly of the 2nd generation DLP LE including the telecentric lens. Figure 6b shows the integrated projection system. The 2nd generation LE completes the ToMax AMT-system and further all claims of WP5 were met.

a)



b)

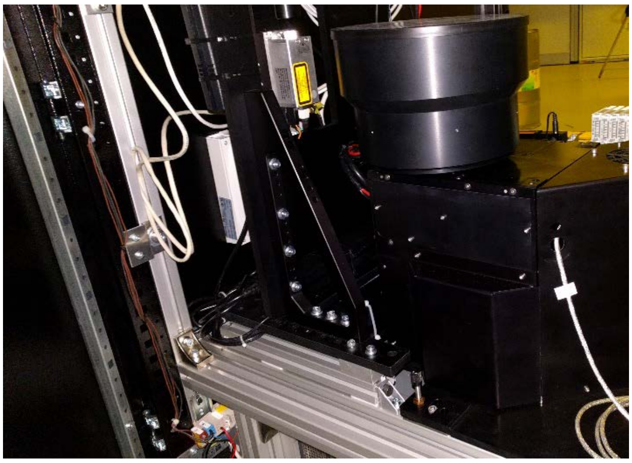


Figure 6: (a) Final assembled 2nd generation DLP LE including the telecentric lens. (b) Integrated LE in the ToMax AMT-system.

Figure 7 shows the result of the combining exposure. After calibrating the system according to D5.4 [4], DLP and laser could be aligned successfully. The left cylinder shows a complete overlap of the laser exposed contour and the inner, DLP exposed structure. Whereas the right cylinder shows one of the first test runs, where the alignment was not fully adjusted. Here the laser contour was shifted and the approximation of the cylindrical structure by pixels is more pronounced.

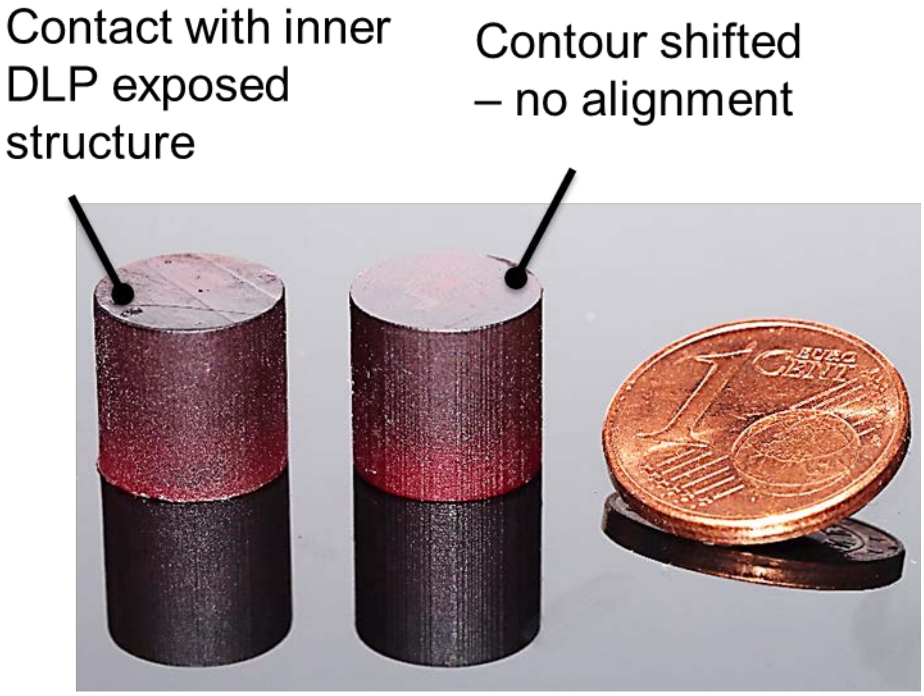


Figure 7: Result of hybrid exposure

Figure 7 shows a printed item of Al_2O_3 in order to demonstrate the processability of filled materials. Thus, all deliverables are fulfilled in time, without delay and WP5 is hereby completed. The demonstrator is fully operational and allows beside the hybrid exposure also the use of laser and DLP separately.

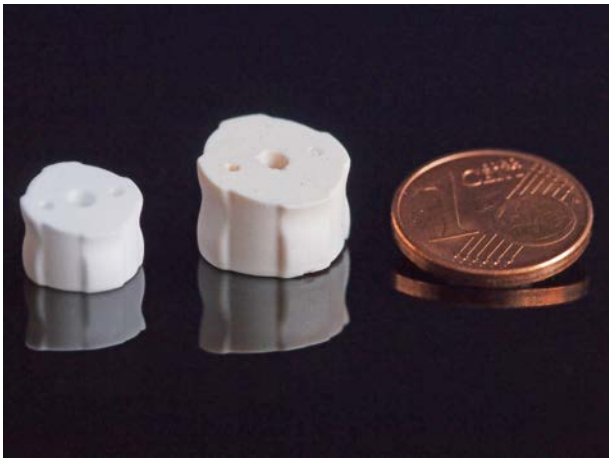


Figure 8: Laser printed item (Al2O3)

3. Overview of the deliverables:

The following table gives an overview of the current status of the WP5 at month 15. The table has been adapted according to the deliverable D 5.1 [1]. For repetition: In the following table the timetable and the associated deliverables of the work packages 4 and 5 are listed. Both work packages are necessary to complete the L-AMT system. Further subsequent steps are listed in the table to provide a detailed approach for providing the L-AMT system.

Start of the project: 1. January 2015 (month 1)

Preparation			
Name	**Timetable (Deadline)**	**Deliverable**	**Status**
Approval of functional specification document (System specification)	June 2015 (Month 6)	D 5.1	✓
Catalogue of requirements for projection system	June 2015 (Month 6)	D 4.1	✓
CAD construction M.1 + M.2	Within June 2015 (Month 6)		✓
Preparation of mechatronic components of M.4	Within June 2015 (Month 6)		✓
Assembly, implementation and testing			
Name	**Deadline**	**Deliverable**	**Status**
Assembly M1, M2	Within January 2016 (Month 12)		✓
Programming and testing mechatronic components	Within January 2016 (Month 12)		✓
Provide heated vat	Within January 2016 (Month 12)	D 5.2	✓
Provide first generation light engine with 1920x1200 pixel based on laser diodes	January 2016 (Month 12)	D 4.2	✓
Provide L-AMT system with first generation LE	April 2016 (Month 15)	D 5.3	✓
Programming and testing Laser-Software	Within June 2016 (Month 18)	Provided earlier	✓

Complete projection system for high throughput machinery including dichroic mirror	June 2016 (Month 24)	D 4.3	✓
Provide calibration system for alignment of laser scanner with light engine	January 2017 (Month 24)		✓
Provide second generation light engine for demonstrator system	January 2017 (Month 24)	D 4.4	✓
Provide L-AMT system with integrated second generation light engine	January 2017 (Month 24)	D 5.4	✓
Provide process conditions for recyclable wash-away supports	January 2017 (Month 24)	D 5.5	✓
Completion of the L-AMT system			
Name	**Deadline**	**Deliverable**	**Status**
Provide report on overall performance (especially interplay between laser scanning system and light engine)	June 2017	D 4.5	✓
Final approval	June 2017 (Month 30)		✓
Expected completion	June 2017 (Month 30)		✓
Provide demonstrator system with 120x75x100mm build volume and 15 µm resolution	June 2017 (Month 30)	D 5.6	✓

4. Table of Content

[1] B. Busetti, „D5.1 Provide system specification“, TU Wien, Wien, Deliverable D 5.1, 2015.

[2] B. Busetti, „D5.2 Provide heated vat for high viscosity resins“, TU Wien, Wien, Deliverable D 5.2, 2015.
[3] B. Busetti, „D5.3 Provide L-AMT system with first generation light engine“, TU Wien, Wien, Deliverable D 5.3, 2016.
[4] B. Busetti, „D5.4 Provide L-AMT system with integrated second generation light engine“, TU Wien, Wien, Deliverable D5.4, Dez. 2016.

Table of figures