As part of an additive manufacturing process in which a UV-curing resin is used to print rods and frameworks, the irradiance of the LED module is to be measured. A total of nine LEDs from Nichia, which are positioned around the nozzle, serve as the UV radiation source for curing the extruded resin (see Fig. 1 link). Three LEDs each form a group (1, 2, 3), in which the distance a and angle α are the same (see Fig. 2). Each LED is also equipped with a lens. This sets a defined beam angle (FOV) (see Fig. 1 right). Six of the LEDs have a beam angle of 30° and illuminate the area of the nozzle exit as well as a part along the printed rod. The other three LEDs have a beam angle of 10° and focus directly on the exit area of the nozzle.

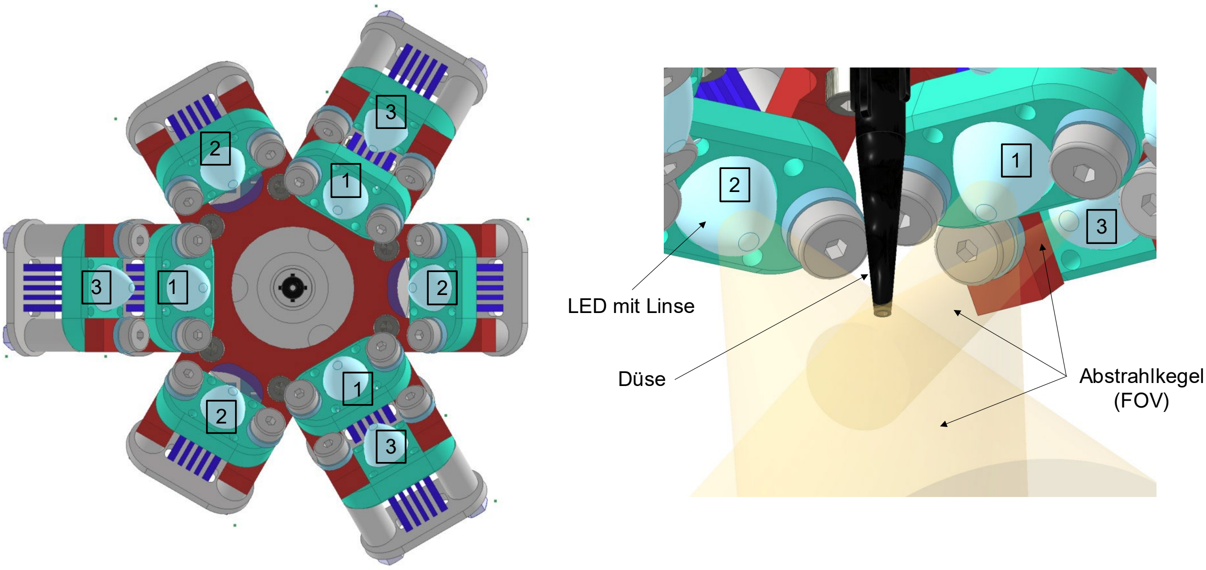
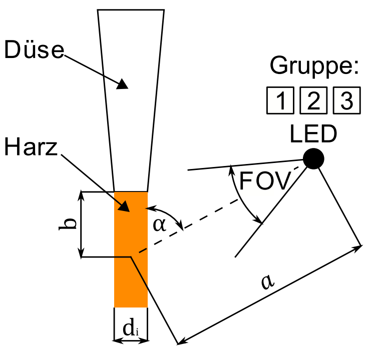


Abbildung 1: Anordnung der LEDs um die Düse und FOV der Linsen



LED Gruppe	Anzahl LEDs	a $[mm]$	b $[mm]$	α [°]	FOV [°]
1	3	58,5	18,4	28	30
2	3	60,2	16,5	37	30
3	3	61,2	4,5	52	10

Abbildung 2: Geometrische Anordnung des LEDs um die Düse

Measurement execution

In order to know which irradiance E_e in the wavelength range of 365 nm actually arrives at the nozzle exit and along the printed rod for the given LED configuration, the mobile measuring device X1-1-RCH-116-4 from Gigahertz-Optik is used for measurement Loaner provided. The device consists of the X1-1 optometer and the RCH-116-4 detector.

For the measurements, the UV detector is placed below the nozzle (see Fig. 3). The irradiance is measured at different distances b from the nozzle exit and at several UV intensities. At each measuring point the LEDs are switched on for two seconds. After these two seconds, the last reading displayed on the optometer is recorded. The pause between two measurements is 5 seconds.

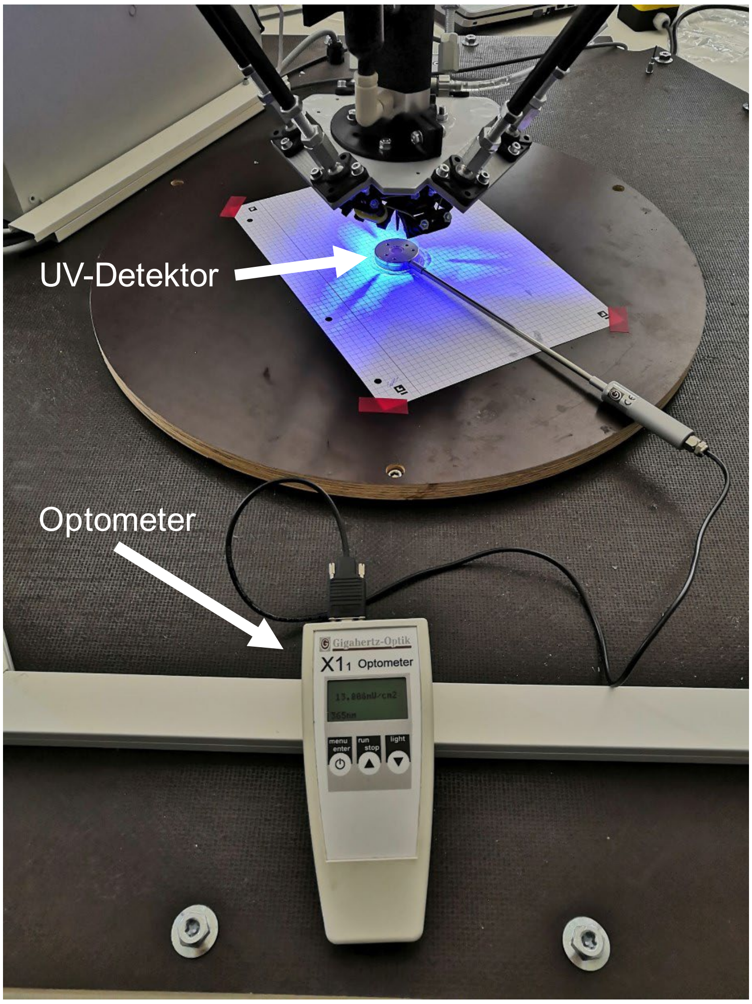


Abbildung 3: Messdurchführung mittels Radiometer

Measurement results

In Fig. 4, the irradiance E_e is shown as a function of the UV intensity for different distances b from the nozzle exit. Each curve corresponds to a certain distance b. It can be clearly seen that the curves rise relatively steeply at the beginning when the UV intensity is low and flatten out or become saturated as the UV intensity increases. At high UV intensities, the electrical power of the LEDs goes directly into power loss or heat output, as temperature measurements have confirmed.

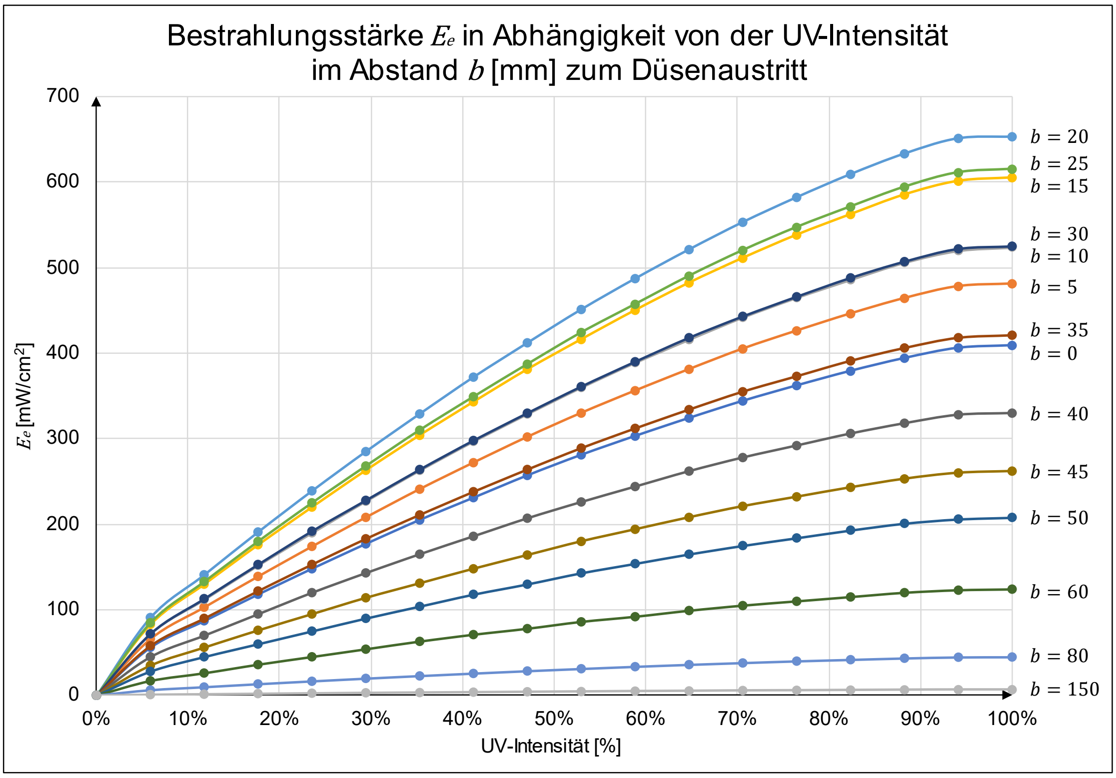


Abbildung 4: Bestrahlungsstärke in Abhängigkeit von der UV-Intensität

Fig. 5 also shows the irradiance depending on the nozzle distance b for different UV intensities. Due to the arrangement of the LEDs, the maximum is at a distance of b=20 mm behind the nozzle (see top curve in Fig. 4).

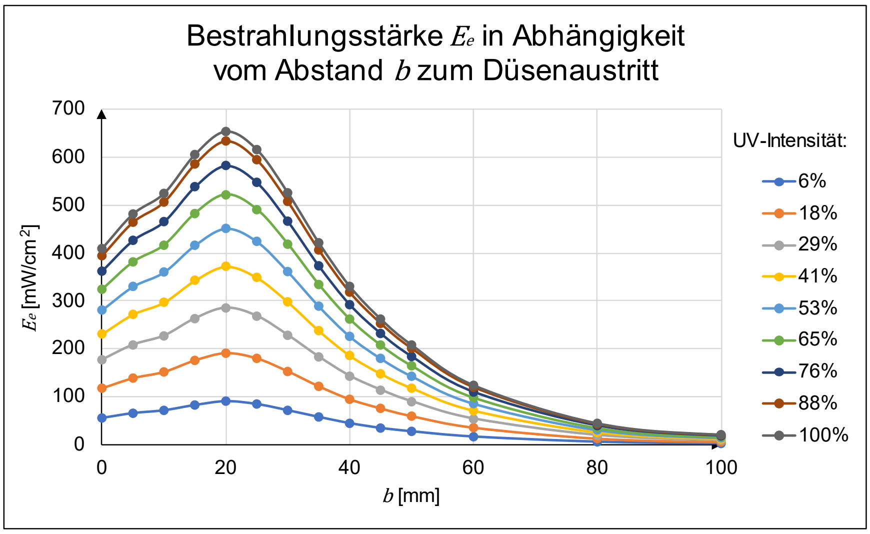


Abbildung 5: Bestrahlungsstärke in Abhängigkeit vom Abstand b zum Düsenaustritt

During the measurement tests, it was found that the irradiance at high UV intensities drops sharply in the first seconds after the LEDs are switched on (several 100 mW/cm^2). The reason for this is the rapid heat development of the LEDs, which leads to power loss. In order to investigate the effect in more detail, additional measurements are carried out in which the irradiance is measured as a function of time. For this purpose, the LEDs are switched on at different UV intensities for 20 seconds each. The measurements are carried out for the distance b=20 mm.

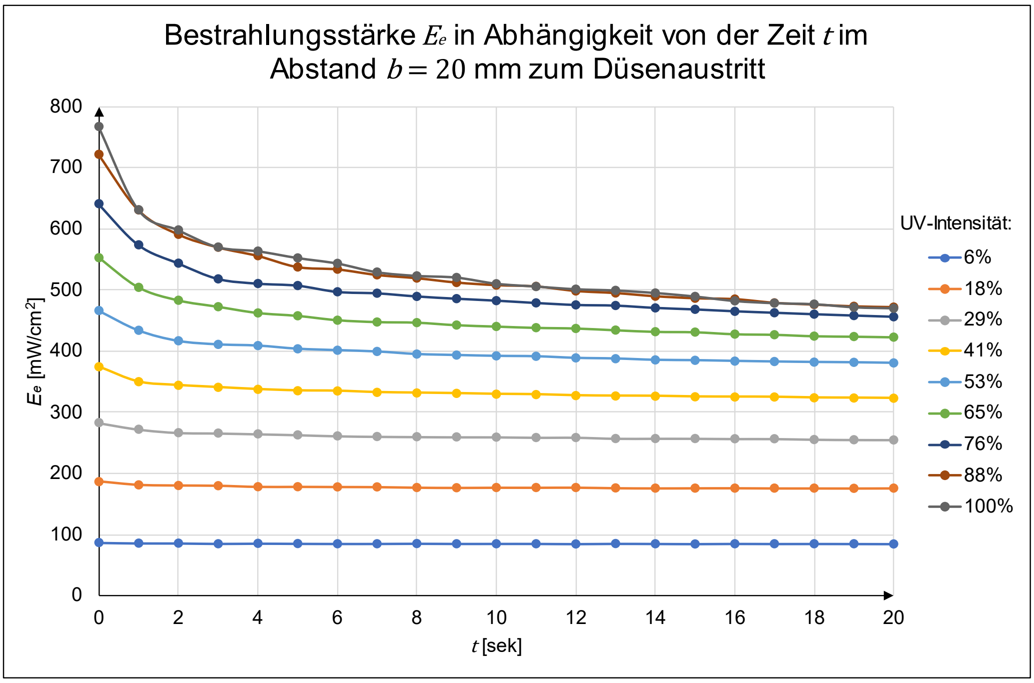


Abbildung 6: Bestrahlungsstärke in Abhängigkeit von der Zeit

The heating of the LEDs can also be clearly seen in the printing results. In Fig. 7, ten bars were printed with the same settings. In the picture above, the bars were printed one after the other. The irradiation intensity of the last bars was no longer sufficient for sufficient curing. In the image below, there was a 60 second break between each rod so that the LEDs could cool down sufficiently.

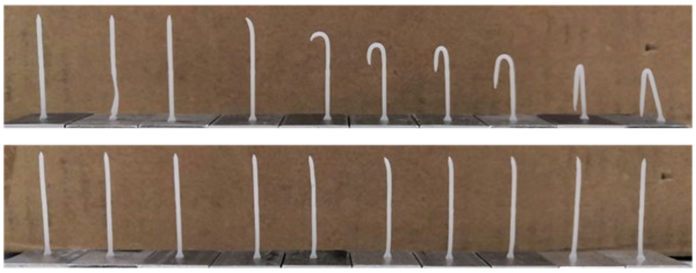


Abbildung 7: Oben: Keine Pause zwischen dem Druckvorgang von zwei Stäben; Unten: 60 Sekunden Pause

Result

With the help of the radiometer from Gigahertz-Optik, the irradiance of the LED configuration could be measured precisely and the power loss of the LEDs at high UV intensities could be shown as a function of time. The next step is to further improve the cooling of the LEDs.