Laser test results

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Setup

These laser tests were performed at UBC in order to estimate the effect of incidence angle on the photoelectron efficiency from a UV laser impinging on an aluminium target. In addition to the behaviour of the untreated target the effect of two different surface treatment methods was investigated. These methods were: - dimpled by rolling a file over the aluminium tape - scratched by running the tape under a weighted block with 80 grit sandpaper twice.

A schematic overview of the setup is shown in Figure 1. A UV laser impinges on a target inside a vacuum chamber. The target holder can be rotated to allow different incidence angles. The target holder is one plate of a capacitor, with the opposite plate connected to a positive voltage. Freed photoelectrons are extracted to the opposite plate, the resulting current pulse can be measured on the target plate. For normalization purposes a photodiode monitors the reflex from the vacuum chamber entrance window. To increase the dynamic range of the PD, the intensity can be modulated with an iris in front of it.

A commercial laser power meter can be placed in the beam path to measure the average energy per laser pulse. Before the actual experiment measurements were made with the power meter both at the indicated position and at the target position inside the chamber to determine the optical transmission. It was found to be 36.3%.

Procedure

For each target a series of runs was taken with different laser incidence angles. At some point during the angle scan it was found that the PE pulseheight (i.e. the signal from the target) would either become too low for the DAQ or too high for the utilized amplifier. In this case the “Energy” control on the laser was adjusted until the signal fit well inside the dynamic range of the system. If this adjustment moved the PD signal outside the dynamic range of its arm of the DAQ the PD iris was adjusted accordingly.

Before and after each run the power meter was placed in the beam path and a reading (averaged over 30s) was taken. The pulse energy of the laser varies wildly, so the pulse energy should not be considered very reliable, most likely there is a 10%-20% uncertainty. The average of both readings was then assumed to be the pulse energy at the mean of the PD spectrum. An example of such a spectrum is in Figure 2.

After this was done for all runs, an average calibration scaling was calculated for all runs that had the same PD iris configuration. This was used to translate the ADC1 value into number of photons on target.

Conversely it is known that for the target arm of the DAQ the amplifier gain is 1.25mV/fC, which was used to convert the PE pulseheight to number of photoelectrons.

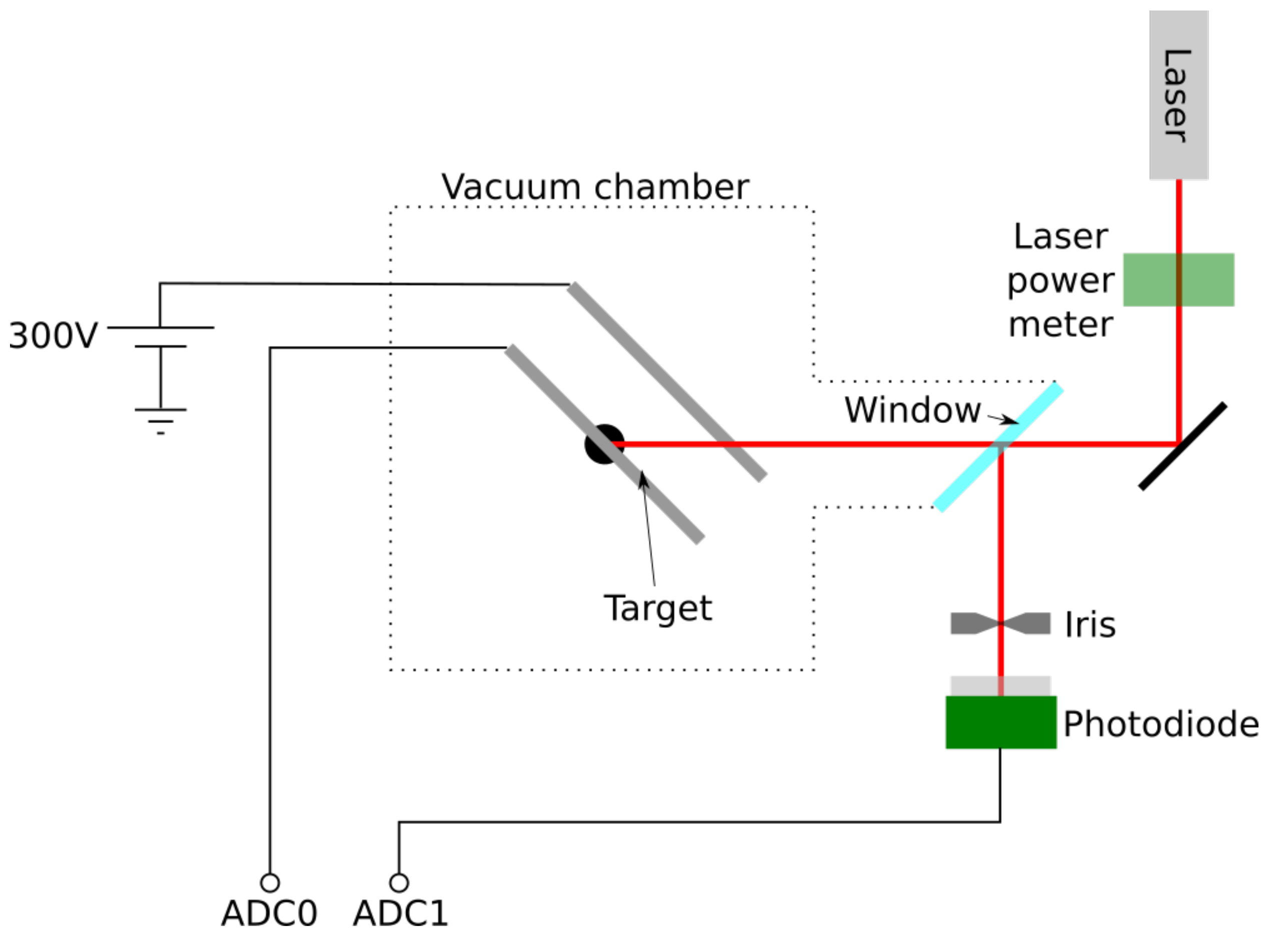


Figure 1: Experimental setup

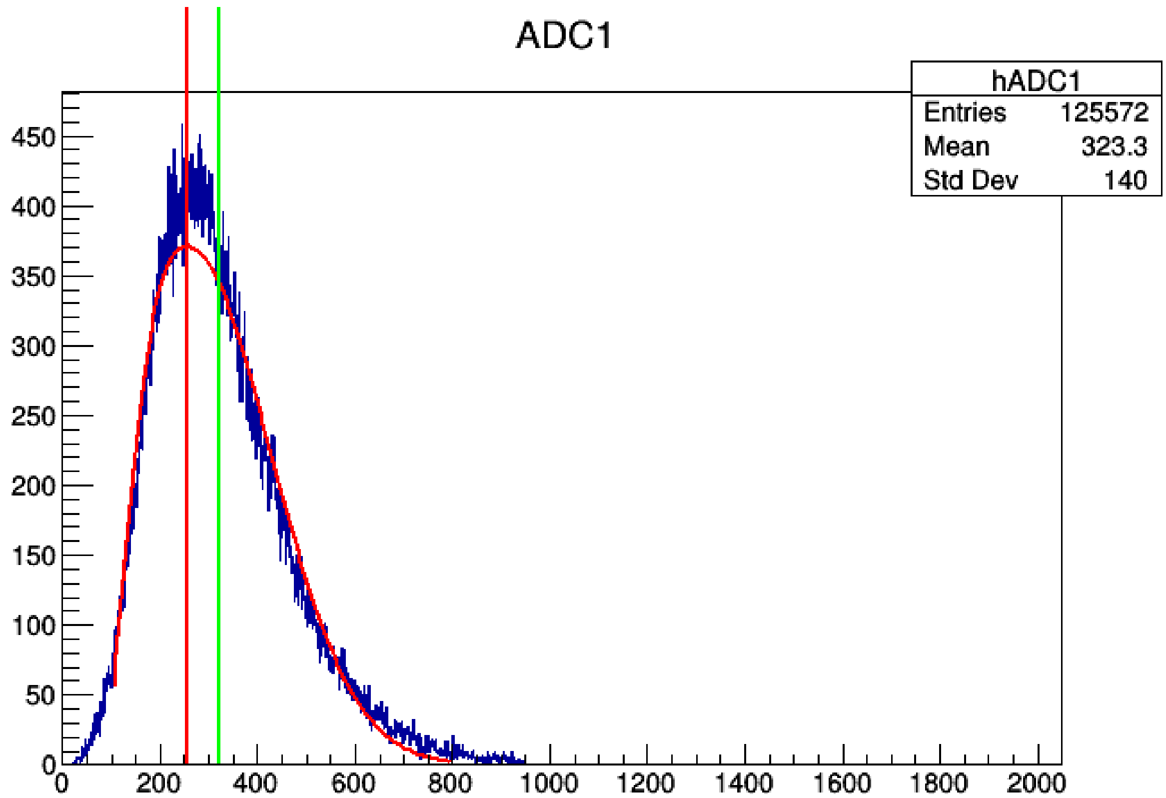
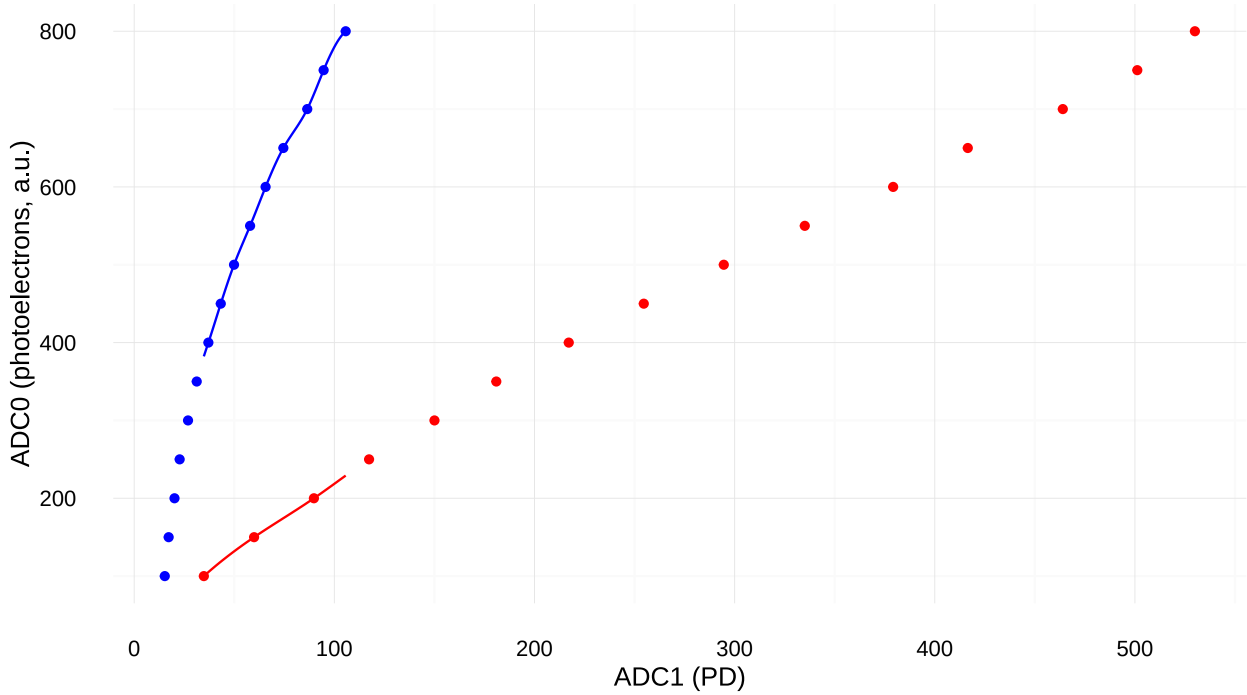
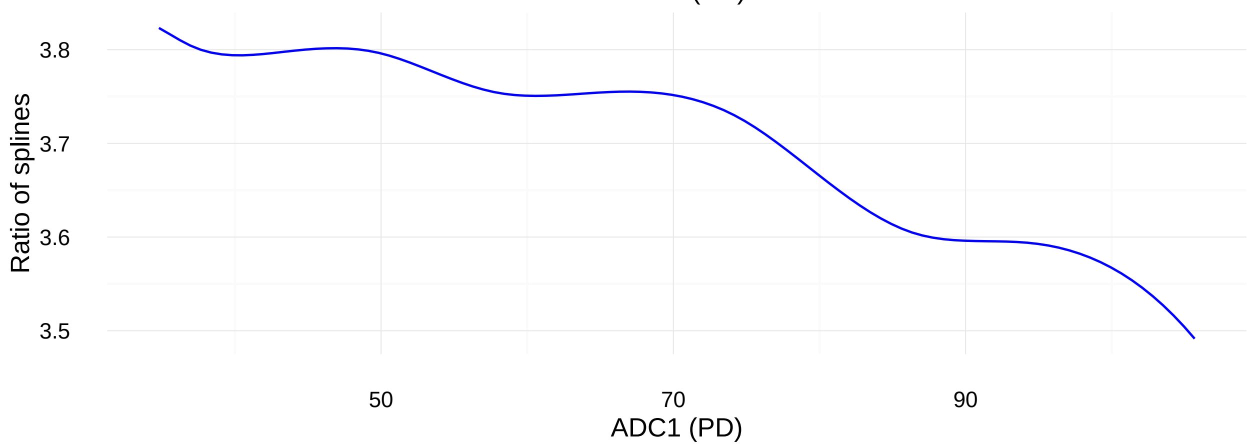


Figure 2: Photodiode spectrum from a typical run, red line is the mode, green line the mean of the fitted skewed gaussian

Complication

During the experiment it became apparent that the efficiency of the sanded target was so high that in order to not saturate the amplifier the laser intensity needed to be turned way down, so low in fact that the power meter no longer registered the pulses. This results in these measurements not being calibrated absolutely. Because this was obvious at time of measurement, the 60° measurement was taken before and after adjusting the iris (the iris was only adjusted once in this angle scan), so the two settings can at least be scaled relative to each other. The following plot shows PE pulse height versus PD pulse height for both iris settings. PE pulse height can be used as a proxy for the number of photons on target, as both are unaffected by the iris. In the overlapping region both data sets are smoothed with a spline, then the ratio of both splines is taken, shown in the second plot.





Clearly the variation isn't very strong, as should be expected, so it suffices to use the average value for the relative scaling. The resulting average ratio is 3.701.

Analysis

After calibrating the histogram of number of photons versus number of photoelectrons slices were taken at different photoelectron numbers. The resulting distributions are mostly quite gaussian, so a gaussian fit was attempted, and if successful the fitted mean recorded with respect to the slice position. Figure 3 shows an example of the uncalibrated histogram. The mentioned slices are vertical, e.g. for an ADC0 value of 600 ± 10.

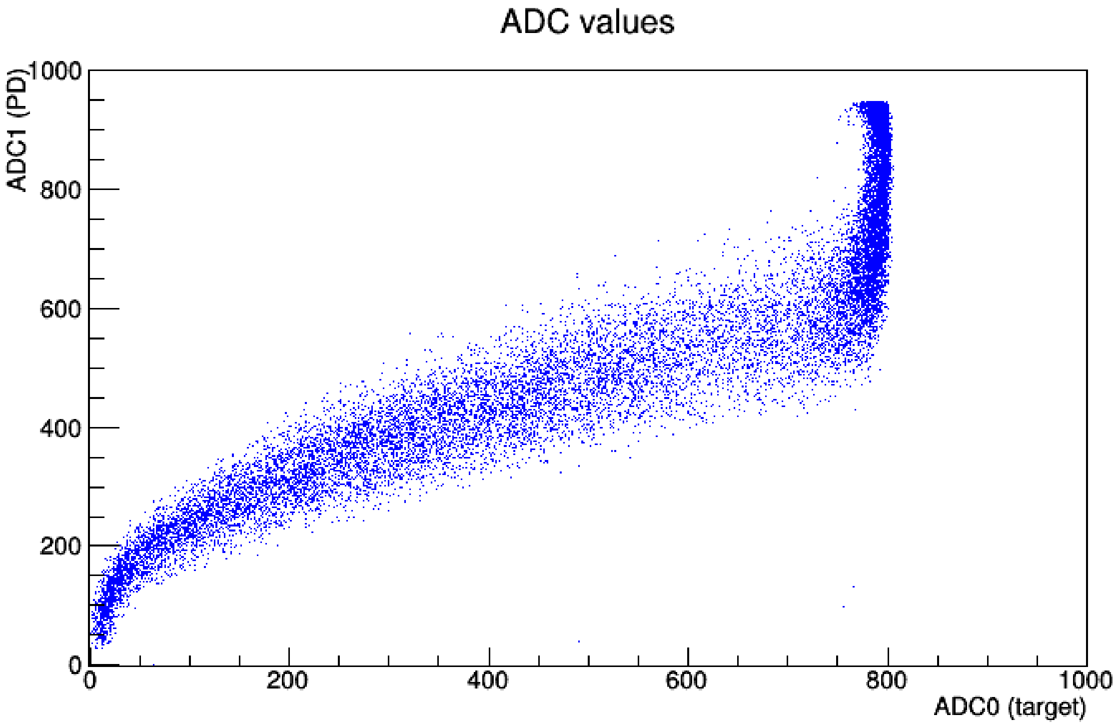


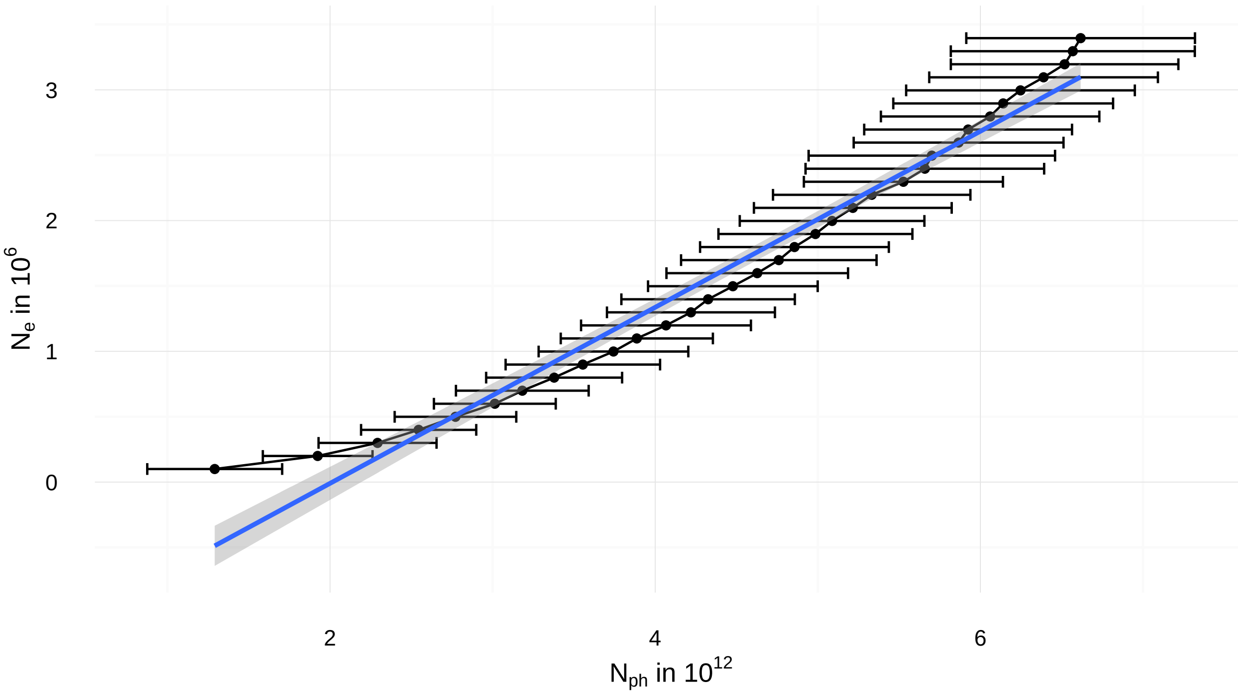
Figure 3: Sample histogram of PD pulse height versus target pulse height

One would expect the ratio of photoelectrons to photons to be constant for a given angle and target, but for whatever experimental reason this was not the case in the given experiment, as evident by the curvature in Figure 3. So in order to investigate the angle dependence it was necessary to only look at one photoelectron slice at a time.

Results

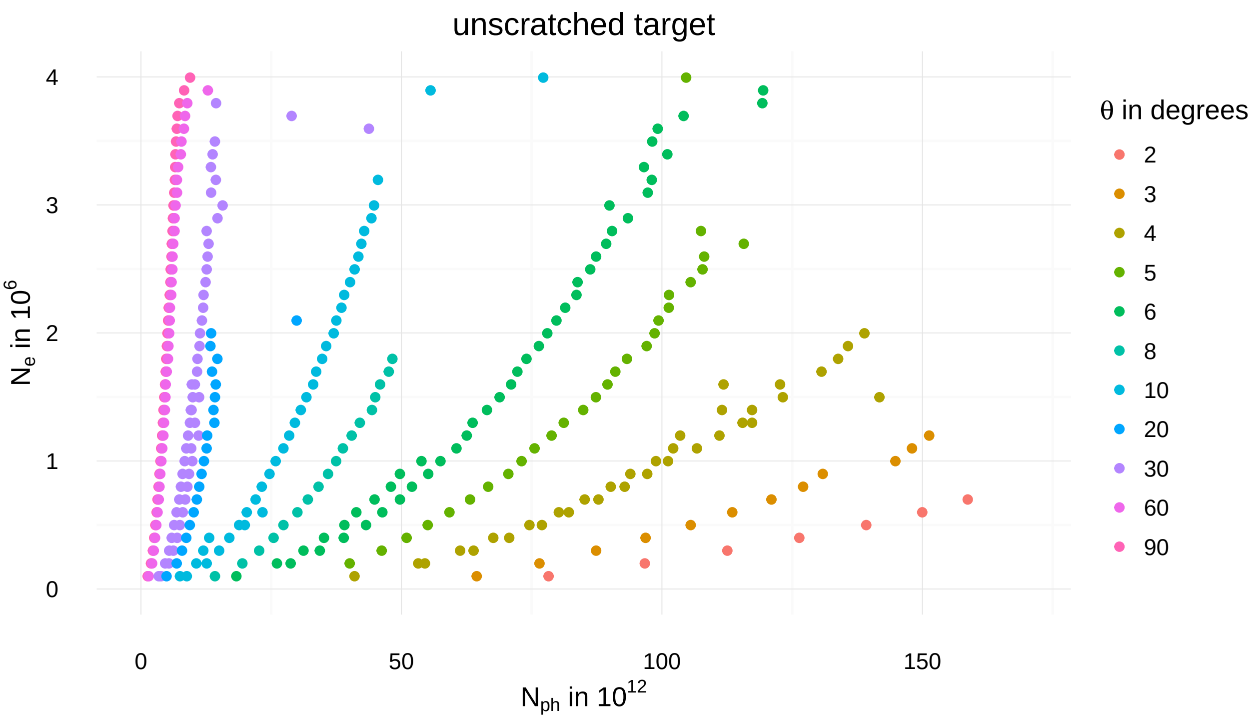
Linearity

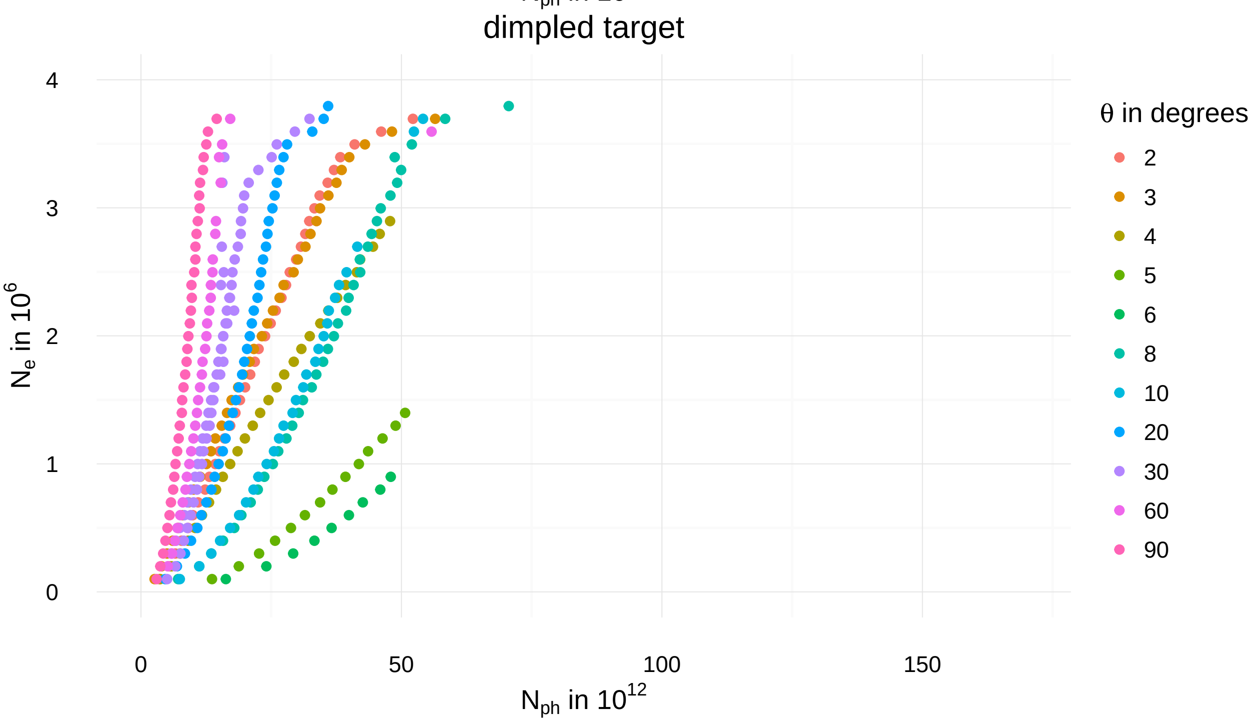
Picking out one of the incidence angles (90°) on the untreated target and fitting a linear regression to the number of photoelectrons versus number of incident photons while also showing error bars indicating the width of the PD distribution shows that while the behaviour is clearly not fully linear as it should be, it's not extremely far from it.

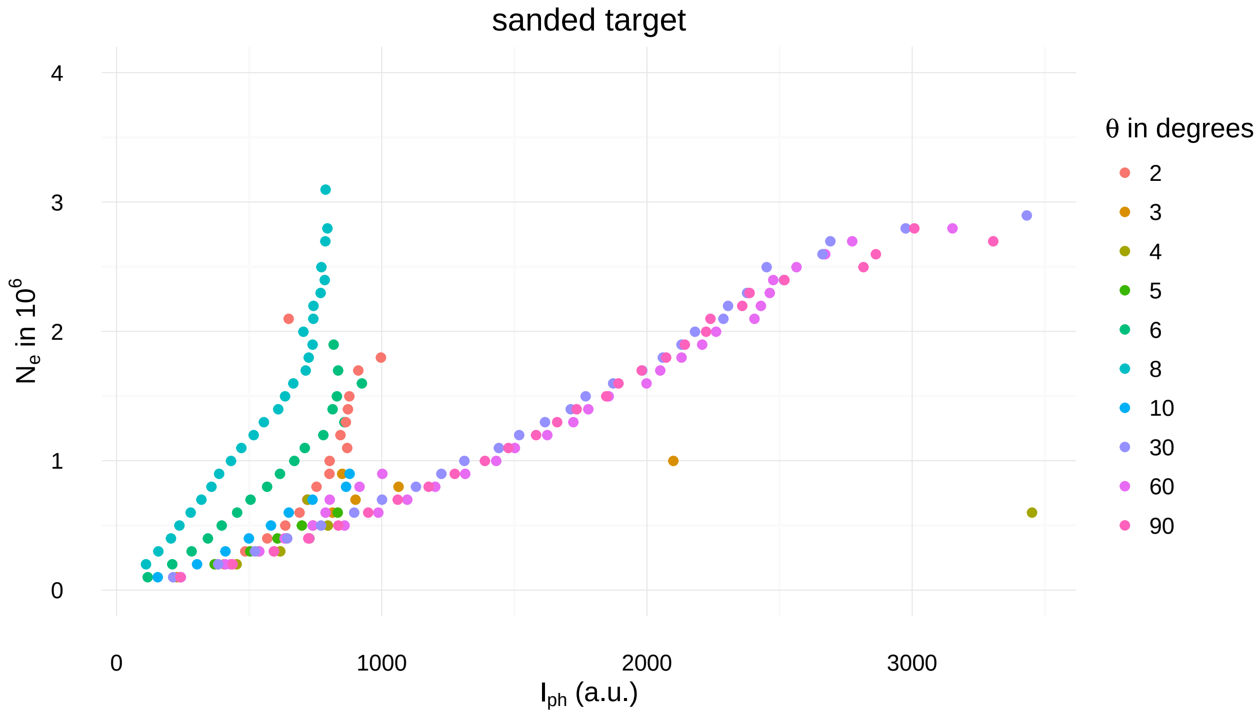


Total number of photoelectrons

The first thing to compare for the three targets is the direct plot of photoelectrons versus photons, which turns out not to be immediately easy to read, because of the many dependencies influencing it. It's further complicated by the fact that the measurements for the sanded target are uncalibrated for the reasons stated above.

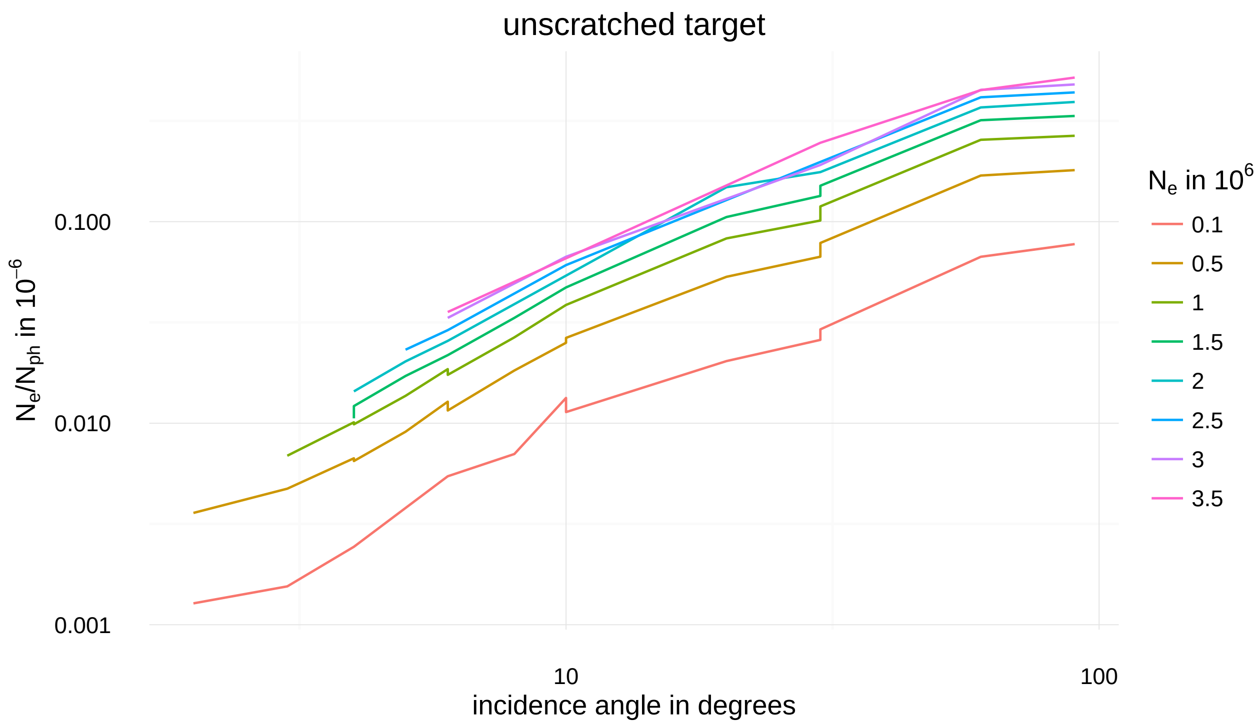

unscratched target
N_e in 10^6
N_{ph} in 10^{12}
0
1
2
3
4
0
50
100
150
θ in degrees
2
3
4
5
6
8
10
20
30
60
90

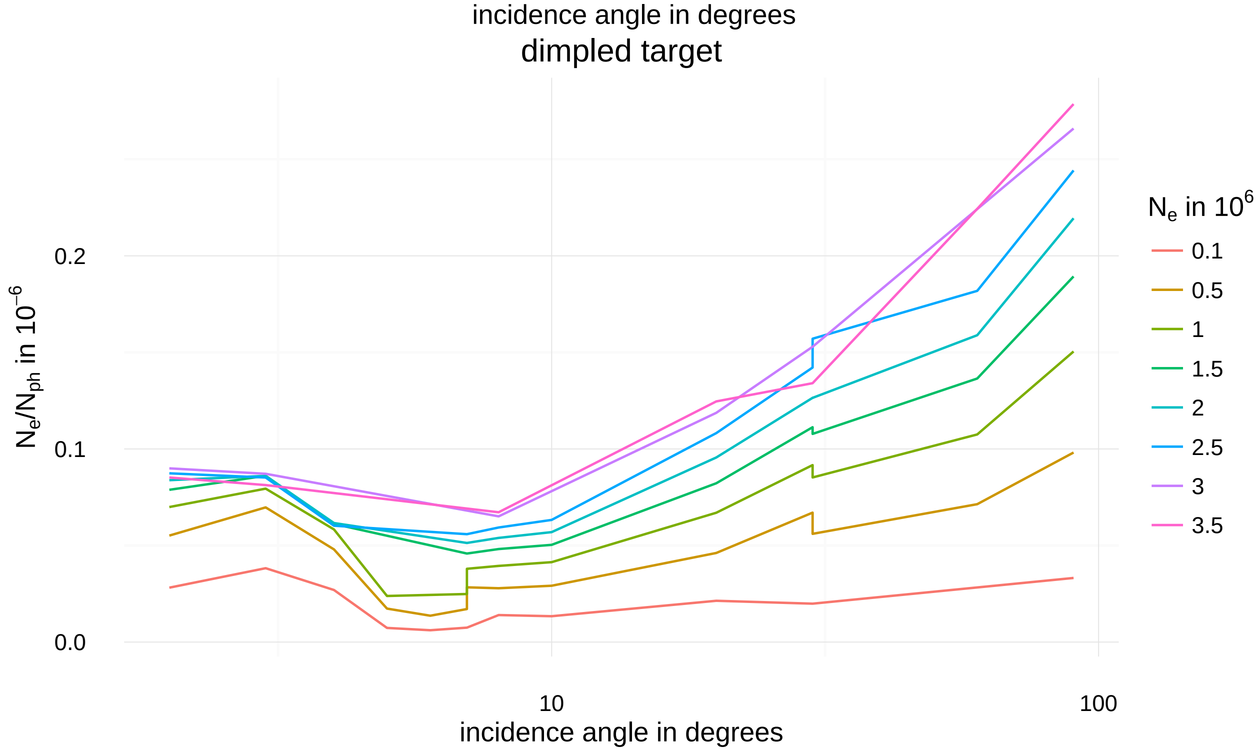

dimpled target
N_e in 10^6
N_{ph} in 10^{12}
0
1
2
3
4
0
50
100
150
θ in degrees
2
3
4
5
6
8
10
20
30
60
90

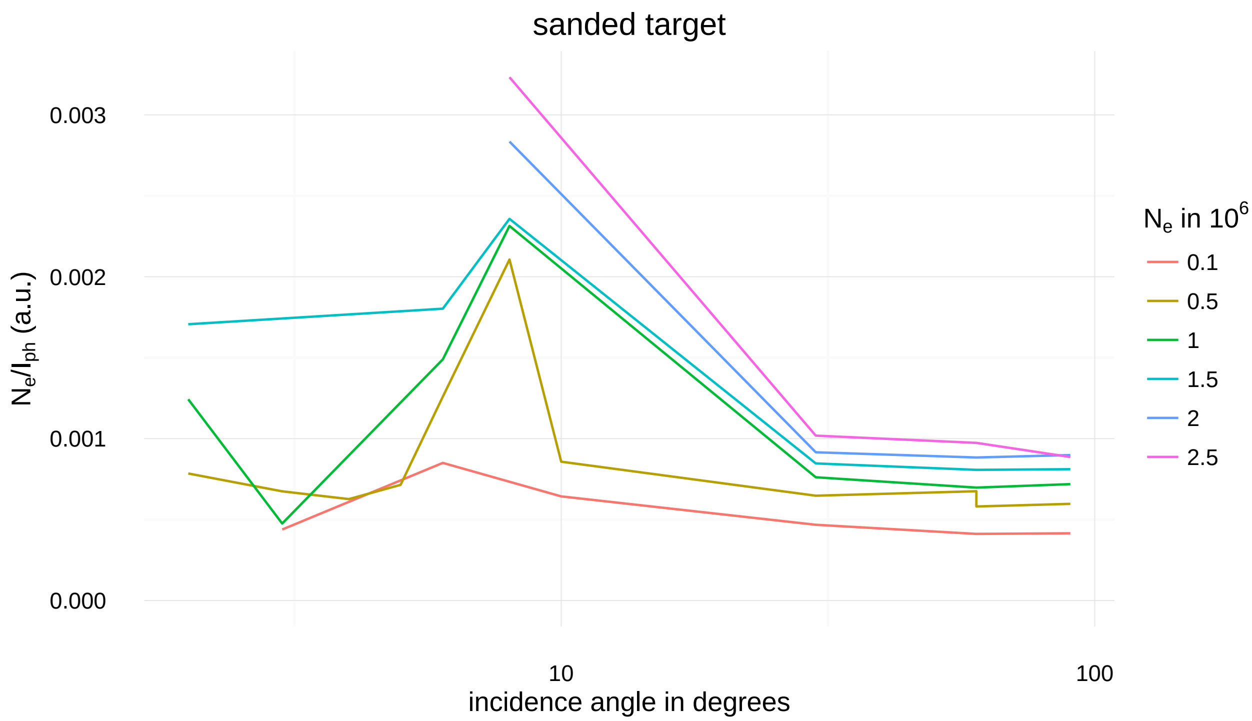


Angular dependence

To show the angular dependence it works better to plot the ratio of photoelectrons to incident photons N_e/N_{ph} versus angle. Since the ratio is not pulse height independent, as mentioned above, it is necessary to examine the behaviour for one photoelectron number slice at a time. This is shown for several photoelectron slices below. Note that for the unscratched target the y-axis is logarithmic due to the extreme angle dependence, while the same is not necessary for the treated targets.


unscratched target
0.100
0.010
0.001
N_e/N_{ph} in 10^{-6}
10
100
incidence angle in degrees
N_e in 10^6
0.1
0.5
1
1.5
2
2.5
3
3.5


dimpled target
0.2
0.1
0.0
N_e/N_{ph} in 10^{-6}
10
100
incidence angle in degrees
N_e in 10^6
0.1
0.5
1
1.5
2
2.5
3
3.5

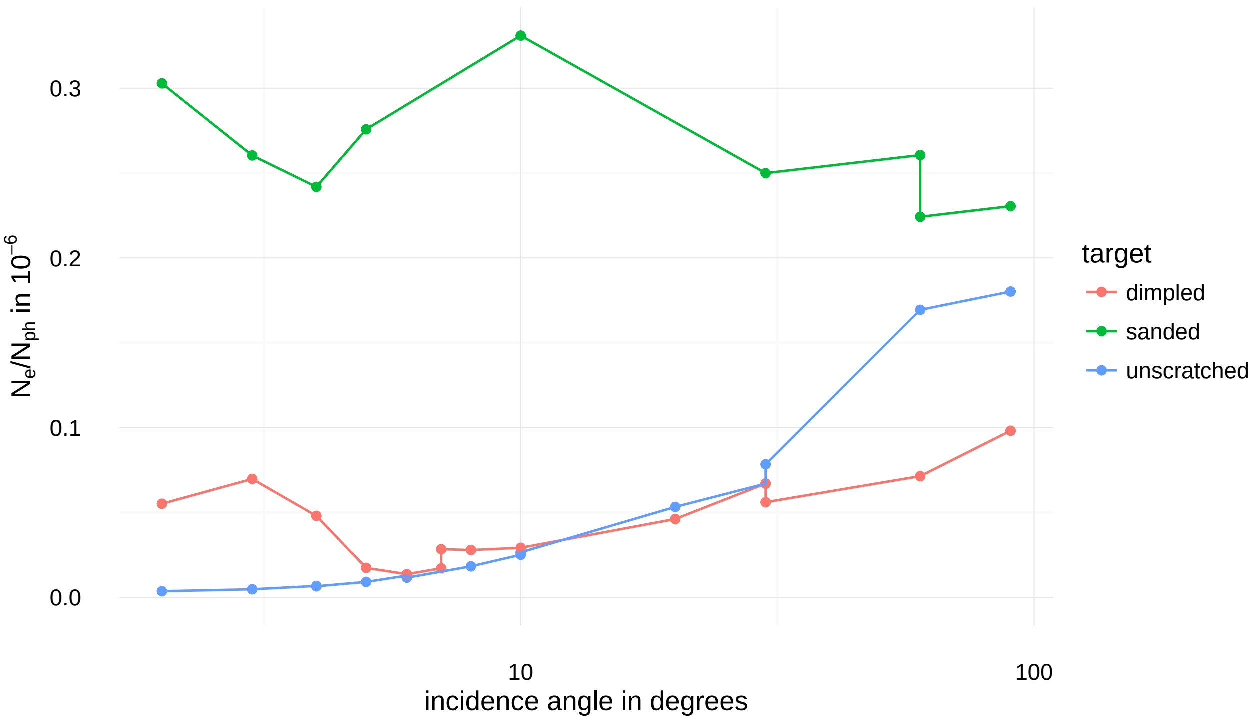


While the untreated target displays a drop of two orders of magnitude going from normal to very glancing incidence, the signal for the dimpled target only drops by about a factor of three. Most interestingly there appears to be no drop at all for the sanded target, maybe even a slight increase.

It is unclear whether the spike at 6° and 8° is real. If so, it is probably connected to the laser hitting the edge of the aluminium tape. The tape direction is perpendicular to the laser path to facilitate the sanding, but that means the target consists of several tape strips next to each other. It is therefore possible that the move to 6-8° just happens to mean most of the beam spot is on a tape edge. In the real experiment every strip will also be hit on-edge, but in terms of reproducibility it is probably best to ignore these points.

Comparison

While the scratched target data is not calibrated, it is possible to estimate the number of photons roughly. Even for the highest laser intensity runs with this target the power meter didn't register most pulses, but it started seeing at least some of them, measuring them to be 10uJ per pulse. It seems a reasonable estimate that the distribution maximum is at something like 8uJ, maybe lower. Using this value allows us to compare the three targets directly. The following plot shows the angle dependence for all three targets for a PE pulse height of ~500000 electrons per pulse. While the absolute y value for the sanded target is uncertain, it definitely lies above the highest unscratched value. Additionally it barely changes with angle, if anything it may slightly increase with lower incidence angle.



Conclusion

It is clear the 80 grit sanded target provides the best photoelectron efficiency, both in absolute numbers and in independence towards incidence angle. The efficiency of photoelectron production for this target is of the order of 3.34e-07, meaning that in order to get 10 photoelectrons out of a given target strip, it needs to be hit by 2.99e+07 photons, which for a 266 nm laser corresponds to a pulse of 22.35 pJ. This needs to be compared with the light distribution from the proposed laser optics in order to determine a requirement for the absolute laser pulse energy. By eyeballing it does look like the requirement for the laser lies several orders of magnitude below the laser intensity used in the UBC tests.