Observation of a large population of optical scatterers in the Advanced LIGO mirrors

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ADDENDUM: Scatterer amplitude distribution.

About an order of magnitude of additional scatterers can be expected to exist undetected below the surface, i.e. hundreds to thousands per square millimeter.

Is it possible to determine the scatterers' albedo amplitude distribution from a coating layer, and are the detected scatterers from the top layer only or from more than one layer?

The answers to these questions are more speculative, because of the limited dynamic range in the CCD camera and poor statistics, yet it may yield suggestive guestimates.

The frequency plot of the logarithm of the luminosity, Figure A1, is fitted reasonably well with a simple Gaussian, $y = a_1 e^{\frac{-(x-Loglum)^2}{w^2}}$, red line in Figure A1. The parameters of the fit are given in Table A1. There is no clear reason why the distribution of scatterer amplitude should be perfectly Gaussian in this scale, but if it is assumed that it is, a small excess of events is expected on the left side from the attenuated light of scatterers located in the next deeper layer. The effect of this second contribution, if not taken into proper account, would be to widen and shift to the left the fitting Gaussian. Indeed the simple Gaussian fit leaves a small excess on the low amplitude side and appears slightly shifted off the right side of the data points.

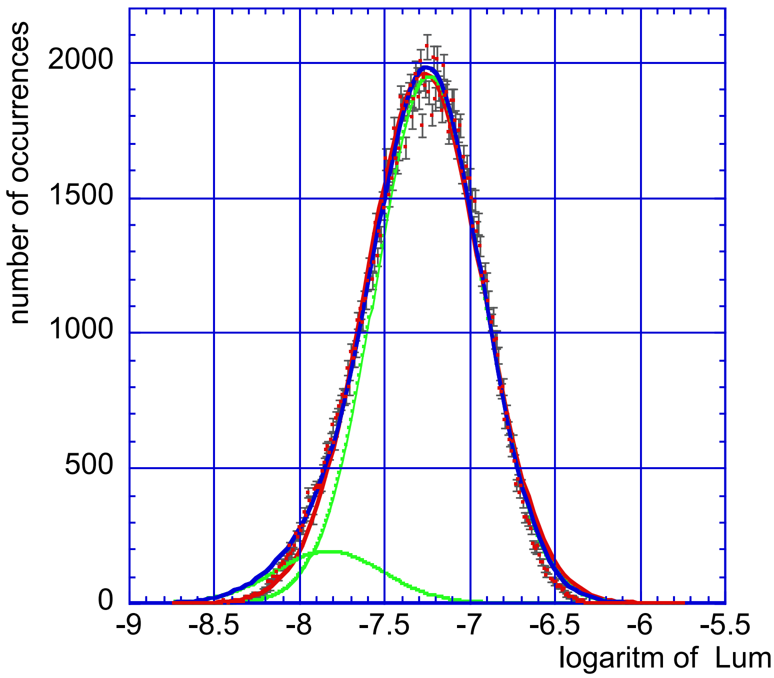

Figure A1: *Dots with error bars, frequency of detected scatterer luminosity vs. logarithm of luminosity (same data of Figure A4). Red line, fit with a single Gaussian function. Blue line, fit with two equal Gaussian functions separated by 0.59 as discussed in text. Green line, the two components of the two-Gaussian fit function. The parameters of the two fits are listed in Table A4.*

	$y = a_1 e^{\frac{-(x-Loglum)^2}{w^2}}$	$y = a_1 e^{\frac{-(x-Loglum)^2}{w^2}} + a_2 e^{\frac{-(x-Loglum+0.59)^2}{w^2}}$
a_1	1958±9	1946±8
a_2	-----	193±15
Log mag.	-7.264±0.002	-7.236±0.002
w	0.482±0.003	0.448±0.003
Chisq	1.0527e+6	7.2253e+5

Table A1: *Parameters of the fits on the data of figure A1.*

According to the data of Figure A1, the next layer is expected to contribute with a attenuation of 75%, which is -0.59 in the log scale, this contribution would have the same shape of the first one, hence a Gaussian with same width. Repeating the fit with two equal Gaussians separated by -0.59 to account for the second layer, $y = a_1 e^{\frac{-(x-Loglum)^2}{w^2}} + a_2 e^{\frac{-(x-Loglum+0.59)^2}{w^2}}$ yields a better fit (parameters also given in Table A1) with a narrower Gaussian (0.448 instead of 0.0482), shifted to the right (-7.236 instead of -7.264), and a Chi squared reduced by 32% (0.722/1.05= 0.68). The sudden signal cutoff below x=-8.2 may be connected with the CCD dark pixel cutoff level. The fitted amplitude of the second Gaussian (a_2=193) is ~10% of the main Gaussian (a_1=1946), while given the unitary slope of DAOPHOT's detection efficiency in Figure 7 (LIGO-P1600325), the second Gaussian would have an expected amplitude ~25% from the second layer and ~6% from the third layer. This may be compatible with the fact that the second layer is made of Silica, which is supposed to be a better glass former may have less scatterers.

While suggestive, this part of the analysis is unsatisfactory without better depth information, which perhaps can be obtained with confocal illumination microscope inspection of the coatings.