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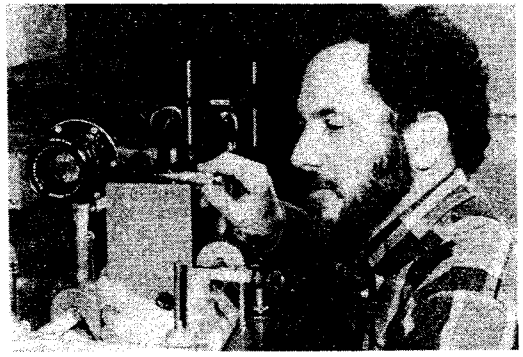
Dialogues in Optics

An interview with Matt Young on the scratch and dig standard for optics

Matt Young *is a physicist with the National Bureau of Standards in Boulder, Colorado. He has published many papers in optics, optical fiber measurements, and optical surface quality. He shared a Department of Commerce Silver Medal for his work in optical fiber measurements. He is the author of the book* Optics, *third edition (Springer, 1986) and is just completing a book on technical writing. Earlier, he was a professor at the University of Waterloo, Rensselaer Polytechnic Institute, and Verrazzano College, and a consultant to General Electric Company, Holobeam,* Optical Spectra *magazine, and the New York State Energy Commission. In 1984, he was Visiting Scientist at the Weizmann Institute of Science. He is now Adjunct Professor at the University of Colorado and a principal lecturer in two NBS short courses. In 1967 he earned a PhD in optics from the University of Rochester.*

He was interviewed by ***Robert E. Fischer,*** *Editor of* Optical Engineering Reports.



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Fischer: For some reason, the scratch and dig standard has become a rather popular and also controversial subject in recent years. Why do you think so?

Young: I can offer a guess as to why it is controversial: The scratch standard is something like the Bible. Everyone has heard of it; most people have an opinion about it and they think they understand it; but very few people have actually read or studied it.also like the Bible. it is sometimes difficult to separate the history from the forklore. In this case the folklore is that the scratch standard can somehow be related to the width of the scratch, and that they tightened up the standard at one time. I don't know why it has become popular, except possibly because optical surface quality has become something of greater importance to measure, perhaps due to high power lasers, than it had been in the past.

Fischer: Is it true that indeed a 60 scratch was somehow "redefined" from 60 micrometers wide to 6 micrometers wide within the past few years?

Young: That isn't exactly what happened. It was actually during the 60s. If I understand it correctly, before then everyone realized that the scratch standard was a cosmetic standard, and that the designation of a scratch depended on its visual appearance when viewed in a certain way. At some time in the 60s, somebody, whose name I will not reveal in order to protect the guilty, decided to allow manufacturers to make their own scratches by defining the scratch in terms of its width instead of its appearance. First they said that a number 10 scratch was 10 micrometers wide, a number 20 scratch was 20 micrometers wide, and so on. Then evidently within a couple of years they realized that they were at least an order of magnitude off and, without telling anybody that an error had been made, revised the standard another time, saying that a number 10 scratch was 1 micrometer wide, a number 20 scratch was 2 micrometers wide, and so on.

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That really didn't work either. If you read the standard carefully, you found out that, even if you did make the scratches yourself, they had to look like the old Frankford Arsenal scratches anyway. So it turned out that that exercise in attempting to designate scratches by their width really was fruitless and didn't work out at all. Nothing has changed except everyone's perception of the standard. People's perception was that the

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standard had been tightened by a factor of 10.

Fischer: Isn't it true that if you look at the new standard it says that the width is for reference only, and only a guideline for the manufacture of the standard?

Young: That is what it says. I don't know what "for reference only" means. In fact, I have measured a number of scratches over the years, but I don't recall any scratches being more than 4 or 5 micrometers wide, and those were enormous—they were number 80! Some of the number 10s were so narrow that we couldn't find them to measure them on a profilometer.

Fischer: Yet in MIL 48497 for opaque materials the equivalent of a 60 scratch is an E, which really *is* 60 micrometers wide. Is E supposed to be the equivalent of a 60 scratch?

Young: I don't know. I am not familiar with that standard. I have been working with the "Scratch and Dig Standard" for visible light almost exclusively.

Fischer: MIL-C-48497A (and a related standard MIL-F-48616) is one that people typically use for opaque materials such as in infrared systems. There was always an apparent equivalence between a 60 scratch and an E (an E is 60 micrometers wide), and we are seeing now that that equivalence really is not true.

Young: I suspect it isn't. Certainly a 60 micrometer scratch is an *enormous* scratch.

Fischer: Maybe at some point we need to reevaluate the specifications for IR materials.

Young: That is entirely possible.

People say that the scratch standard is for people who think that optics are for looking at *rather than looking* through. *I would like to ask them, would they take a new car home with a big scratch on it? Odds are they wouldn't. So there is some psychological value to the scratch standard, if nothing else.*

or digs on the surface, means when viewed in this way, from 25 cm distance, and that is something you *can* achieve. But if you allow me to have a microscope, I will find a scratch on *any* surface you give me.standard as it now exists for someone to buy a microscope and start looking at small regions on a surface. He *will* find scratches.

You have got to keep remembering that the scratch standard is a cosmetic standard; sometimes they call it a beauty standard. The value of it is that it is a workmanship standard; if you were to buy a spectacle lens with a bunch of scratches across it, you would begin to wonder what else they messed up, and you would probably not be unreasonable in rejecting it—even though after a few weeks it will have scratches on it anyway.

Fischer: When you think about some of our military equipment getting out in the field, the degradation just due to cleanliness must be orders of magnitude greater than that due to the scratches it left the factory with.

Young: I imagine so.

Fischer: Is there a better way to measure scratches and digs than a comparative test, such as a scatterometer?

Young: Well, if would certainly be more costly to do anything else. All you have to do now is backlight the sample with a relatively narrow beam of light and look at it 5 - 10 degrees off-axis and see what you see. That is the real value of the scratch and dig standard.

save that situation. The amount of light, of the differential scattering cross section if you want to say that, depends too much on the details of the scratch's cross section, and the width is not the dominant factor.

Fischer: Since scratches have little functional effect on performance, do you think looser specifications should be adopted for non-commercial systems?

Young: I don't know if I would say "looser specifications," because a number 80 scratch is fairly gross, and if you specify a surface as having an 80 scratch, that would be a fairly

	Objective measurement	Subjective measurement
Performance standard	MTF Veiling glare Gloss	Picture quality
Not performance standard	Dig standard TIS	Scratch standard

loose specification itself. I think the thing is to recognize that the standard is not a performance standard, and you shouldn't sit around arguing whether a particular scratch is a 60 or an 80, because if it is close the

is on a reticle or a field lens. There it could be quite visible.

Fischer: So all the hoopla, all the confusion, and all the controversy should just go away and become something of the past, because the fact is that the standard *is* a workmanship standard and a cosmetic standard, and for comparison only, and people should accept it in that context.

Young: I wish they would. They also shouldn't fight or try to split hairs whether to accept something or not. If it is *grossly* out of spec, say it is bad workmanship and reject it. But give the benefit of the doubt to the piece of glass that you're looking at, since it is a loose standard and not a performance standard.

Fischer: I referred before to MIL-48497 for opaque surfaces as in infrared systems, and in thermal imaging IR systems the effects of surface defects may be far more severe since the area of the imperfection will likely appear at the ambient system temperature rather than the scene temperature. So we have to be careful and not attempt to correlate the effects of a visible to an IR system, or a visible and a laser system.

Young: Yes, it is important to recognize that the scratch and dig standard really is for

Young: That is entirely possible.

Fischer: We all know about the cosmetic implications of scratches and digs, but what about functional implications? What about your general feeling if you were to buy a camera lens with a scratch on it? Would you take it home and use it?

Young: Ah, that's the problem: That the scratch standard, with some exceptions, is simply *not* a performance standard. The presence of a scratch on a surface is of *no* consequence whatsoever except perhaps as a standard of workmanship. You hear people say that the scratch standard is for people who think that optics are for looking *at* rather than looking *through*. I would like to ask them the question, would they take a new car home with a big scratch on it? Odds are they wouldn't. So there is some psychological value to the scratch standard, if nothing else.

Fischer: Do you feel that military and industrial customers could save money with more functionally related specifications, therefore reducing these requirements?

Young: I have no doubt that they could. But they would have to develop a new standard.

Fischer: Any guess either in dollars or in percent of components produced as to what the rejection rate is, due to not meeting tight cosmetic standards?

Young: I have no idea. I can tell you, though, that there are quite sizable industries that sell only rejected optics.

Fischer: Lionel Baker of SIRA in England told me that the Japanese camera industry doesn't even have standards for scratches and digs, because they don't produce finished lenses with scratches and digs. Any comments?

Young: Just one comment on the specification "no" surface defects: Some people misuse the scratch standards. That is one of the unfortunate side-effects of the attempt to make the standard quantitative. The standard is that, when viewed in a certain way, with the naked eye from a typical distance a scratch should look like a 10 if it is a 10. The specification 0 - 0, that is to say no scratches the real value of the scratch and dig standard.

Fischer: You bring up an interesting point, and that is that with the standards not only for scratches and digs, but also for adhesion of coatings, abrasion of coatings, and others, part of the rationale for these standards is that they be cost-effective. A good example is the cellophane tape of the adhesion standard. But it is exceptionally cost-effective and relatively consistent, and it would cost a fortune to produce a fancy piece of equipment to try to pull the coating off.

There certainly seems to be evidence that damage inside a laser cavity or to a mirror occurs perferentially at the site of a scratch.

Young: And you don't need any training to use the tape. The scratch and dig standards require only relatively little training. Although the people who are in charge of the standard, I must confess, can see in a brightly lit room with a fluorescent light defects that I can't find at all, except perhaps with very careful scrutiny in a dark room with a little help from a lens. As you train yourself, you do see more and more.

Fischer: Of course laser systems and high energy systems do have a more stringent scratch and dig requirement.

Young: There certainly seems to be evidence that damage inside a laser cavity or to a mirror occurs perferentially at the site of a scratch. And you can argue that the damage threshold ought to be related to the width of a defect. If that is true, then *a* scratch standard becomes a performance standard, but *the* scratch standard really doesn't apply because the appearance of the scratch is simply not related to the width of the scratch. You would have to develop a completely new standard based on the measured width of the scratch, and that would become difficult because you would have to scan the surface in some fashion. As far as I can tell, no form of extinction meter or scattering meter would around arguing whether a particular scratch is a 60 or an 80, because if it is close the surface is good enough.

Fischer: Of course there must be a lot of judgment calls by inspectors, particular inspectors rejecting or not rejecting a particular system.

Young: That is why a subjective standard is difficult to apply. It is sort of like the National Basketball Association, where offensive charging has not been called against a star player in several years.

Fischer: In your *Applied Optics* article you made the point that

> although scratches on a surface are very visible, in general they contribute only a small fraction of the total light scattered by the surface. Thus, unless a surface is located in or near an image or object plane, the presence of a scratch is likely to be irrelevant to the performance of an instrument,

and that is what we keep coming back to, to emphasize that the standard is more of a workmanship standard.

Young: The other exception, other than the possibility of laser damage, is when a scratch

Young: Yes, it is important to recognize that the scratch and dig standard really is for visible optics and incoherent sources. A scratch on a very small lens would be nearly invisible in a normal visible system with incoherent light, but in a laser system with coherent light it will cast a very strong shadow or diffraction pattern. So some form of scratch standard can be a performance standard for laser light. But the existing scratch standard is not that standard.

Sometimes, people think that because a standard is objective and yields a number, it is a performance standard. Not so! Some measurements can be objective and give you a precisely defined number, and yet not be a performance standard. TIS and the dig standard are examples of that, becuase they are precisely measured quantities. Meanwhile even a subjective measurement can be a performance standard in certain areas. I like to make a little 2 × 2 matrix (reproduced here) to show this. As you can see, the nature of the measurement does not determine the nature of the standard. All the boxes are filled in.

Fischer: Thank you very much, Matt. I trust that this interview will go a long way to clarify the issues and confusion regarding scratch and dig standards.