SM-6

SM-6 is a developer specially formulated to combat the effects of high intensity reciprocity law departure encountered in pulsed laser holography, especially in the giant q-switched pulse time domain of nano- and picoseconds. It was discovered by the author and a biomedical engineering student working on the endoholography project at Northwestern University during the summer of 1986. The goal of this noble experiment was to be able to take in vivo single beam reflection holograms of anything the cigarette sized holographic endoscopic fiber optic device could fit into, using a pulsed laser. We never anticipated that simply recording Denisyuk holograms with a Ruby laser could be such agony.

The problem lies in severe departure from the basic multiplication equation for exposure doses. A usable density for a nice, bright, SBR holo processed with CWC2 developer and Pyrochrome bleach comes with 100 uJ\cm2 of 633 nm irradiation. A one second exposure time with 100 uW\cm2 incident flux would give the same effect as 100 seconds with 1 uW\cm2. A thousandth of a second should suffice if the flux were one thousand times as large as that at one second, which would be 100 mW instead of uW \cm2. And if a full Watt per square centimeter would fall on the plate it would require an exposure time of a millionth of a second, (uS), and a kiloWatt\cm2 would require a nanosecond to expose properly, and so on. But the real life application doesn't follow the arithmetic when the times get into the uS region. The exposure times are near the relaxation times for the AgBr crystals, and the crystals very quickly forget that they saw any light. The plates may be exposed to those high levels of power, but the silver bromide crystal may have blinked during the brief fraction of a second they were being irradiated. The nanosecond exposed holographic plate does not develop to the same density as one exposed for one second, even though the total energy received was the same in both cases. The processing must compensate for this in one way or another.

We became familiar with the quality of the reflection holographic image of a standard test object recorded with a variety of expsoures using Helium-Neon 633 nm light on 4 by 5 inch Agfa 8E75HD plates processed in combinations of the usual assortment of developers (CWC2, Holodev 602, Pyrochrome, D-19) and bleaches (CWPBQ2, Holobleach 608, Ferrics Nitrate and EDTA, and Pyrochrome). But when the Ruby laser beam was introduced into the set up and delivered a variety of energies from threshold to its maximum on plates processed in the above soups, it was always the same result; underexposure.

So then we tried doping the above developers with varying amounts of phenidone, as we knew from Fermilab Bubble Chamber days that 1.5 grams of phenidone per liter of Kodak D-19 helped make good exposures on Agfa 10E75 with stretched ruby pulses in the tens of microseconds range. This brew was helpful, but never really seemed to give us the same kind of brightness that we had come to expect from the long He-Ne exposures.

We were then putting phenidone into any developer formula we could get our hands on. We were studying Benton's PAAP and I told Salim to add 2.5 instead of 1.5 g of Phenidone. He was slightly affected by the night before, and had already put in the phenidone, but didn't remember putting in any amount that had a .5 in it. He thought that he had put a full five grams in the mixture, and I told him to put in a full gram more just in case he had actually put in only half a gram.

We put four exposures of medium energy onto a test plate amd for the first time we reached saturated densities on a Ruby-exposed plate! We thought that we had way too much phenidone in the developer and that the plate was just fogged overall because of uncontrolled development activity. But in an area of the plate that had lowered light levels because it was exposed by a bright fringe which had been diffracted off the edge of the cardboard which we had been using to block three-quarters of the plate so we could fit four on it had just a little teaser of color. So we shot a new tester at lower energy levels, starting from threshold of the laser and we got excellent quality; just as good as He-Ne exposures, the only difference being that the ruby beam was not spatially filtered.

We verified that he indeed had made a mistake and put in 5 grams of phenidone instead of .5, plus the extra one gram that I had suggested, so the developer was christened SM-6 for Salim's Mistake with 6 grams of Phenidone. Six grams proved to be the magic number, as later tests of the formula using less phenidone did not develop up to the same densities while ten grams of phenidone in the basic PAAP formulation gave lower efficiencies because of overall developer fog.

Salim's Mistake is a lucky break because everyone puts just a gram or two of phenidone in developers, and would never even consider six full grams. But this is a new type of developer for silver halide photo-sensitive materials used in a not very common situation. The quickest photographs are taken with exposures of tens of microseconds; laser pulses are 1,000 to 1,000,000 times shorter. These unprecedented exposure times require departure from what is normally expected of the behaviour of the chemistry.

This developer has an incredible amount of reducing power, and it will fog a fresh, out of the box put directly into a tray of developer 8E75HD plate in four minutes to a density of about .3, and a 10E75 plate to the same darkness in about two minutes. These are the upper limit developing times for those materials in this developer. This is probably the reason why this developer is so successful; the solution acts like a hairpin trigger for any silver bromide grains which might have a foggy notion that they saw the light but aren't too sure about it and it kicks them over the edge and gets them to develop. Safelights must really be safe when processing with SM-6 to avoid development of anything but the holographic fringe system.

In the first trials, the developer was followed by the Pyrochrome bleach, so that we could get shrinkage automatically down from the long red Ruby wavelength to something oranger, so that He-Ne light exiting a fiber could be used as the replay source. We also found that Fe EDTA benign bleach could be used, for exact laser color, but it not very useful for white light reflection holography since that deep red is not too visible to the eye. But it can make a very bright transmission hologram, brighter than a hologram bleached in 'Chrome with the same development and exposure. For the thriftiest use of photons, don't bleach but fix, as you can get by with a density of less than 1.0 and still get a viewable image.

This developer was tested against Ilford SP678C, Pierre Boone's recipe in the Third Symposium on Display Holography Proceedings, and Holodev 602 pulsed, and always came up the winner. It is used regularly by Holicon Corporation for their pulsed work, and the artist Anait Stephens. Further investigation is planned to see if this developer is usable for reciprocity departure at the other end of the spectrum, that of low intensity, in particular for diode laser holography at 780 nm.