Preliminary Research Report on Canon 580EX II Flash Failures

By Jim Clark & Tim Ambrose, Research and Development
LPA Design

Background:

Since the launch of its PocketWizard MiniTT1 and FlexTT5 models in early 2009, LPA Design (A.K.A. PocketWizard) has been receiving periodic calls and reports from customers who are using their Canon 580EX II flashes with the PocketWizard ControlTL radios and expressing concern that perhaps their flash may have been damaged by using a PocketWizard radio trigger with it.

As of the time of this report (Jan, 2011), there are about 120-140 PocketWizard customers who have reported having one or more 580EX II flashes damaged with common symptoms over the past 18+ months.

If the failure mode was related to our product, this would work out to less than 0.5% of our MiniTT1/FlexTT5 radio units which were connected to a flash that failed and less than 1% of the 580EX II flashes that were connected were damaged.

LPA Design has conducted a serious in-depth investigation for several months as we continue to collect data and evidence of the specifics of the failure mode. In addition we have just started the outside research assistance of analytical chemistry professor Giuseppe Petrucci at the University of Vermont.

Research:

The symptom of the failure is that the 580EX II will no longer output controlled amounts of light. It will only output full power dumps. This full power dump will happen even on a pre-flash, therefore leaving no stored energy within the capacitor left for a main flash exposure.

The testing quickly revealed that an IGBT (transistor) within the flash is damaged. This part is made by Renesas (part # RJP4301).

The IGBT is used to turn off the flow of current through the flash tube when the desired amount of light has been reached. This IGBT is also used to control (modulate) the brightness of the light when in HSS (High Speed Sync) with the help of a fiber optic cable feeding a light sensor within the main body.

Although LPA Design has been able to identify the symptom of the problem, LPA Design has not been able to trace the cause of the problem to our PocketWizard products and we have no knowledge of the incidence rates of this problem arising independently without PocketWizard, i.e. some number of 580EX II flashes likely fail without PocketWizard ControlTL radios interacting with them. We received reports of this IGBT failure in all spectrums of use. It spans multiple different Canon camera models, below X-Sync and above in HSS (more often in HSS), TTL or manual modes and on any version of firmware that the PocketWizard MiniTT1 and FlexTT5 have had in public release. Even brand new flashes could fail. We have ruled out heat buildup as a cause since several have failed within the first dozen shots after being pulled out of the camera bag. This is all based on verbal descriptions from customers.

It also has failed as many times with a PocketWizard AC5 RF Soft Shield as it has failed without using the AC5. So there appears to be no change in occurrence when using the AC5 or AC7.

We purchased many of the failed flashes from end users so we could take them apart and study the other common elements between the units that failed.

Most significant observations:

One common theme was that ALL failed flash units have had the IGBT damaged and needed replacement.

The second common theme was that ALL failed units have visible signs of electrical arcing / electrical discharge from one or more ends of the flash tube to the metal reflector.

Repaired units that have only the IGBT replaced will frequently fail again within relatively short time periods when used directly on a Canon camera without a PocketWizard radio involved.

So it became clear that the IGBT wasn't the only failure component within the system.

Eventually we found that the flash head (tube/reflector) was also bad and showed visible signs of ash and soot buildup around the ends of the flash tube. Sparks and electrical arcing were apparently taking place.

Replacement of the flash heads solved the failure problems and the flashes could no longer be made to fail with or without a PocketWizard radio.

Below are examples of the 580EX II flash heads that were causing IGBT failures to repeat –

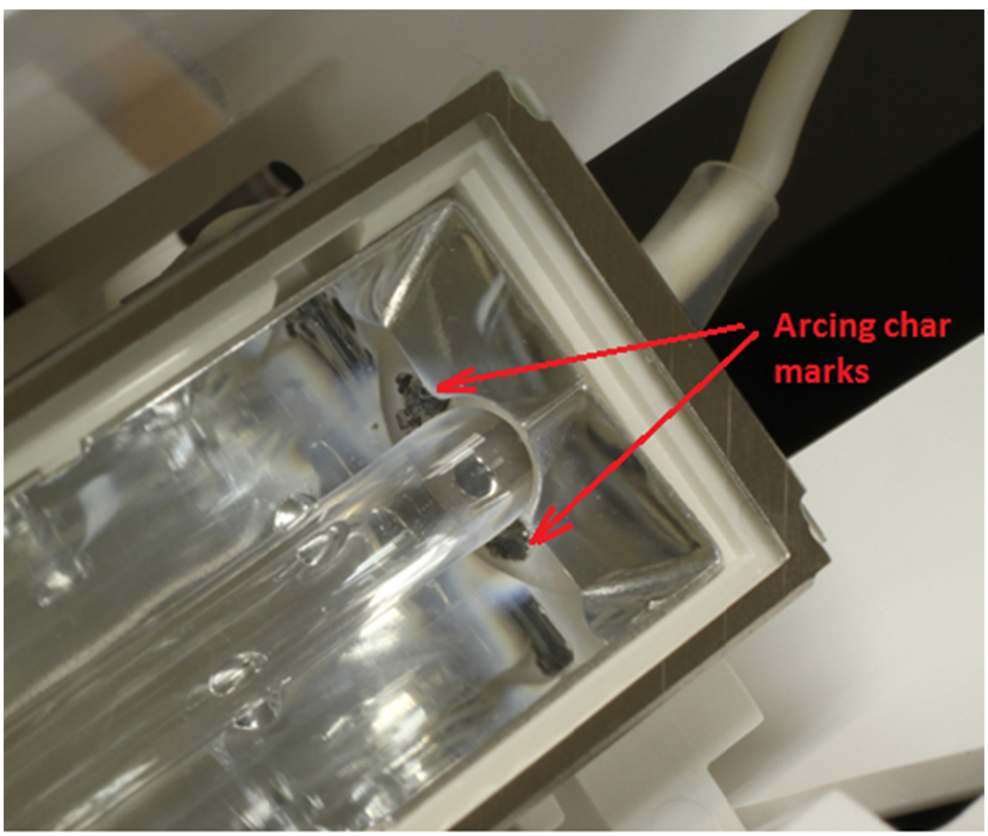

Figure 1: Flash tube end showing black soot behind tube on rubber mount. Also shows possible oxidization of metal reflector near rubber end seal.

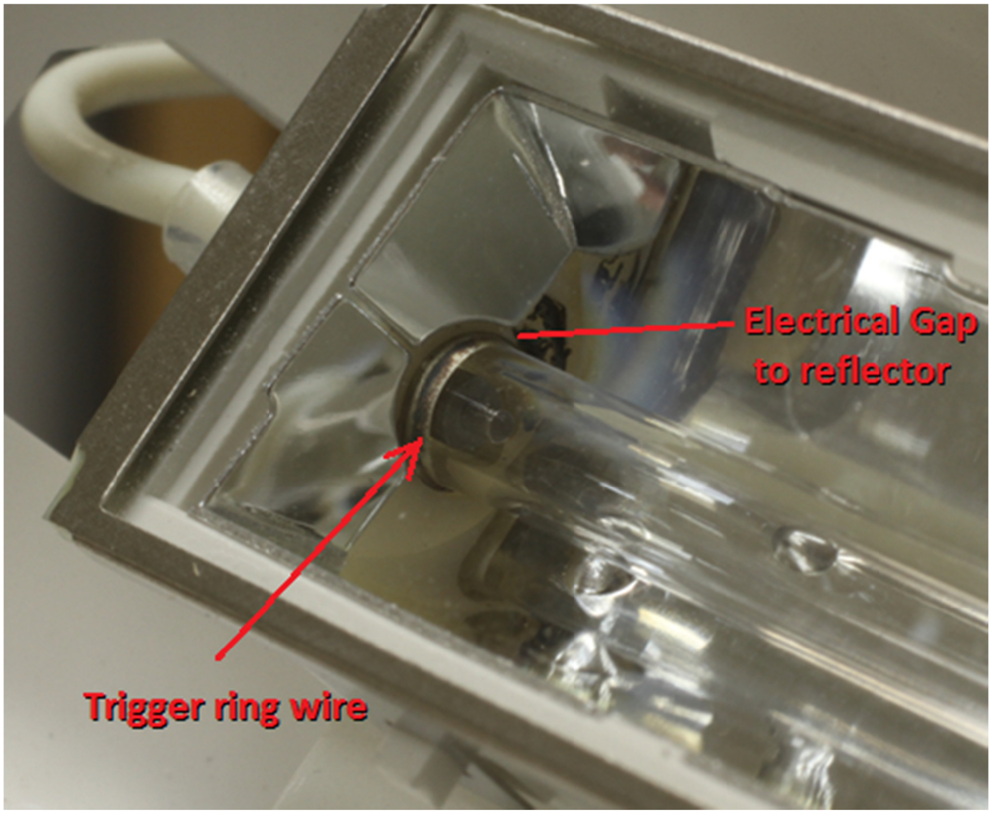

Figure 2: Flash tube end with trigger ring showing black soot behind tube on rubber mount. Also shows possible oxidization of metal reflector near rubber end seal.

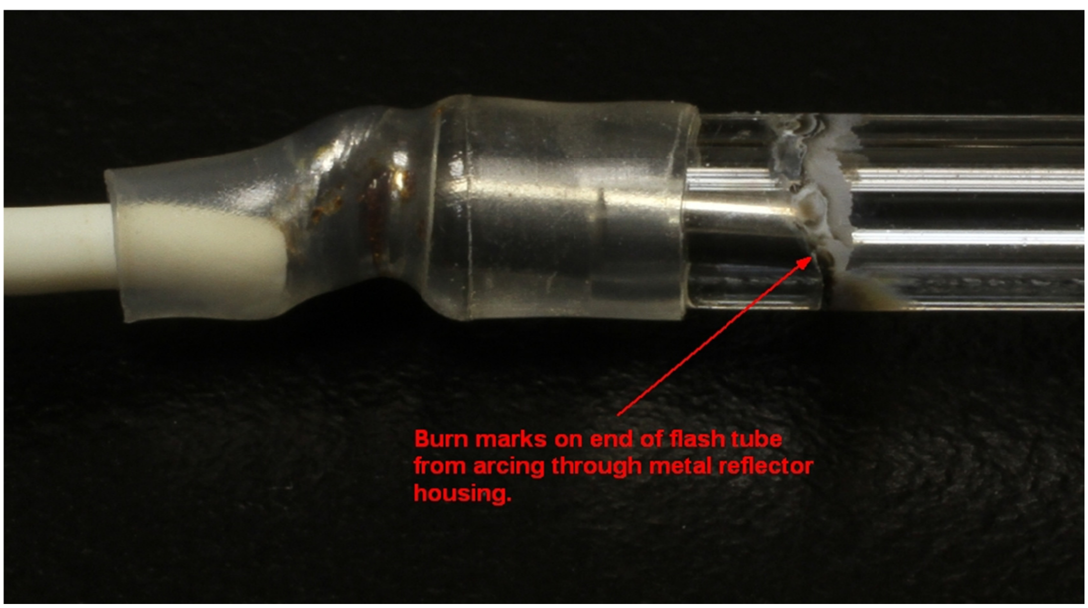

Figure 3: In more severe cases the flash tube glass is charred in a ring around where the metal reflector housing is near the tube.

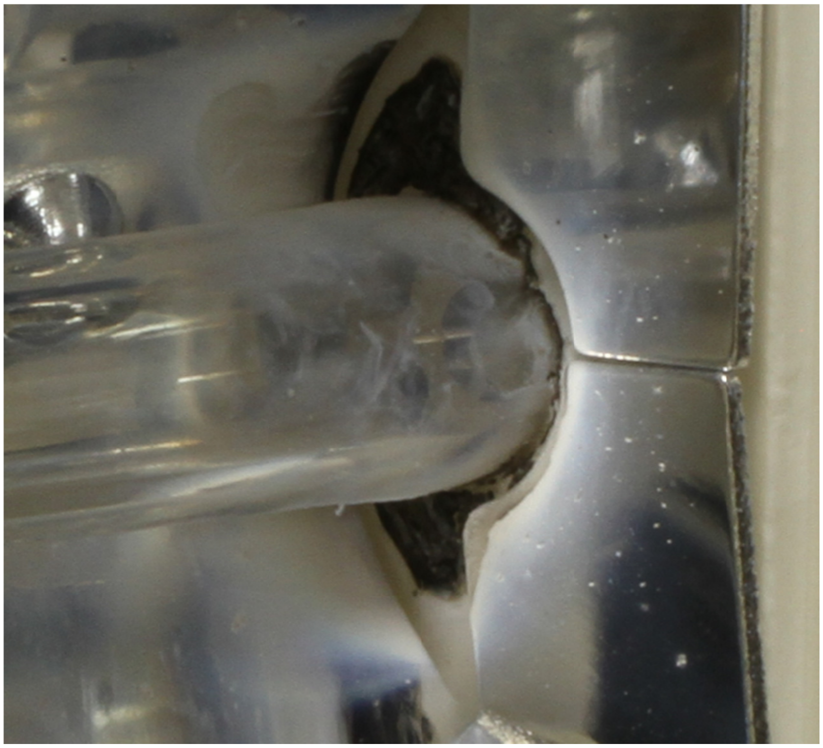

Figure 4: Another example of soot and electrical damage at end of flash tube.

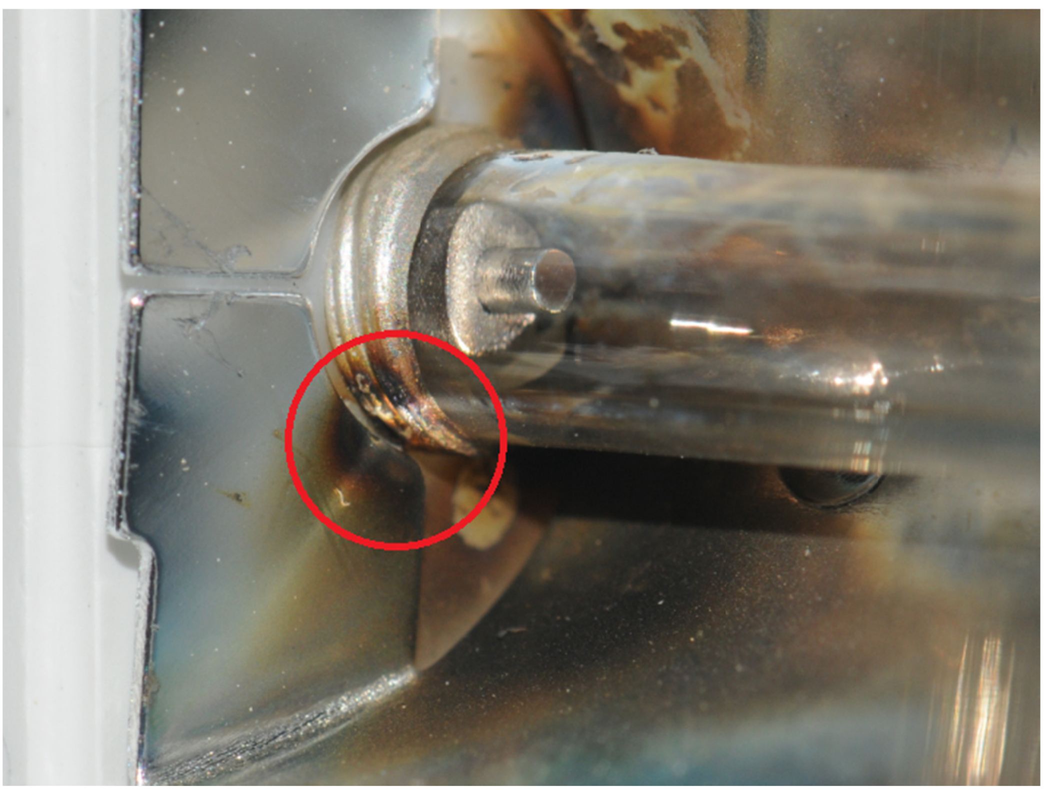

Figure 5: Example of damage from reflector to trigger ring after electrical arcing

Electrical Analysis of Failure Mode:

We captured failure events as well as good working units to verify the problem using an oscilloscope.

For reference, IGBT current is sensed by measuring voltage across a 0.01 ohm 1% resistor in line with the IGBT emitter lead.

Below is an example of a failure we have captured –

Figure 6: In the middle of a High Speed Sync pulse train, the IGBT fails and shorts Collector to Emitter.

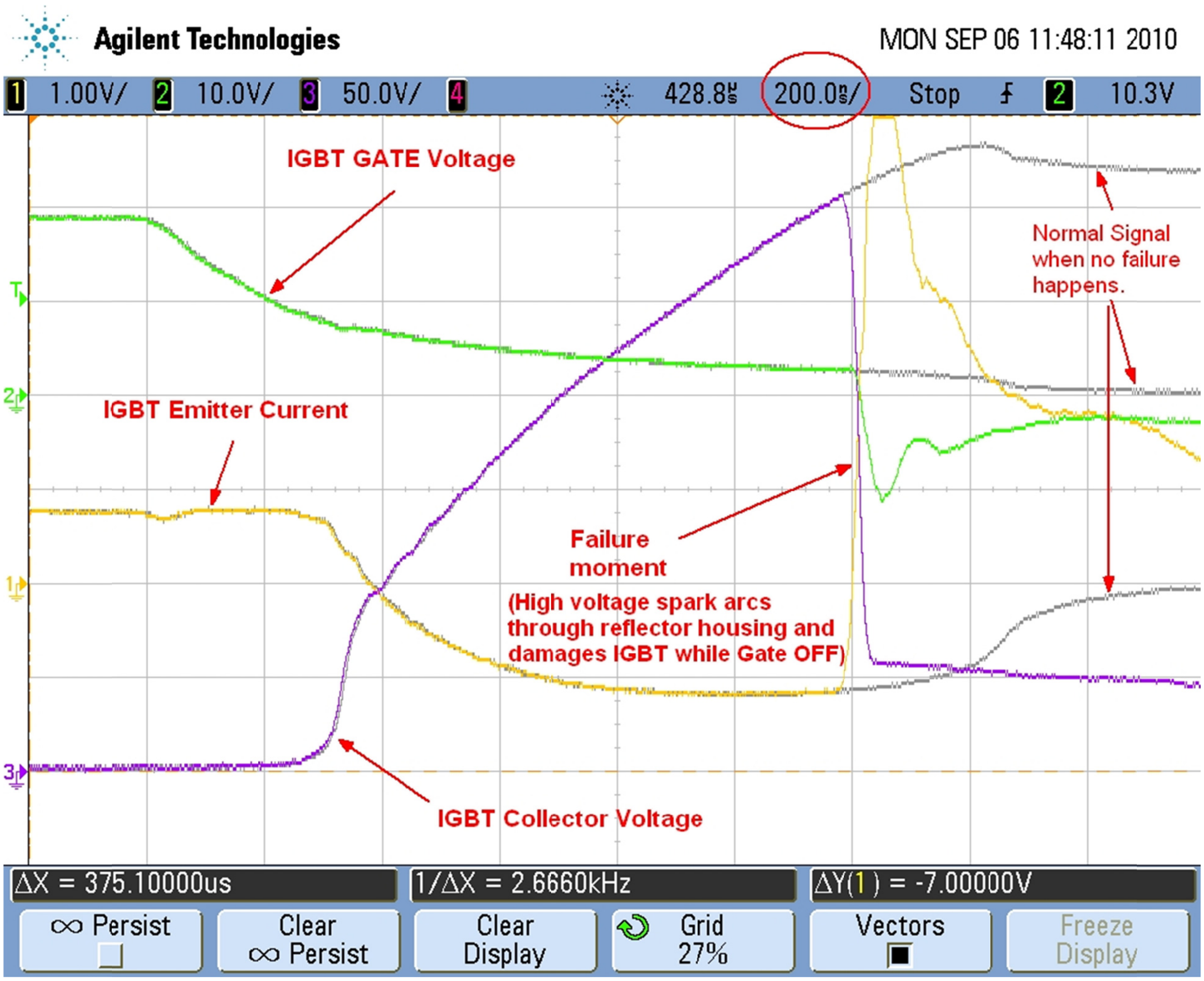

Figure 7: Close up view of IGBT electrical signals. Note that the IGBT gate was turning off when the spark jumped to the reflector and then into the collector of the IGBT.

Making the flash more prone to failure:

In many cases (but not all) we are seeing that the fiber optic cable has either pulled back some from the front edge of the housing or it has a kink / pinch in the fiber line which might be causing some reduction in feedback to the sensor.

We are seeing that this fiber optic cable can make the flash more sensitive to having a spark arc from the negative flash tube cathode over to the trigger ring of the tube.

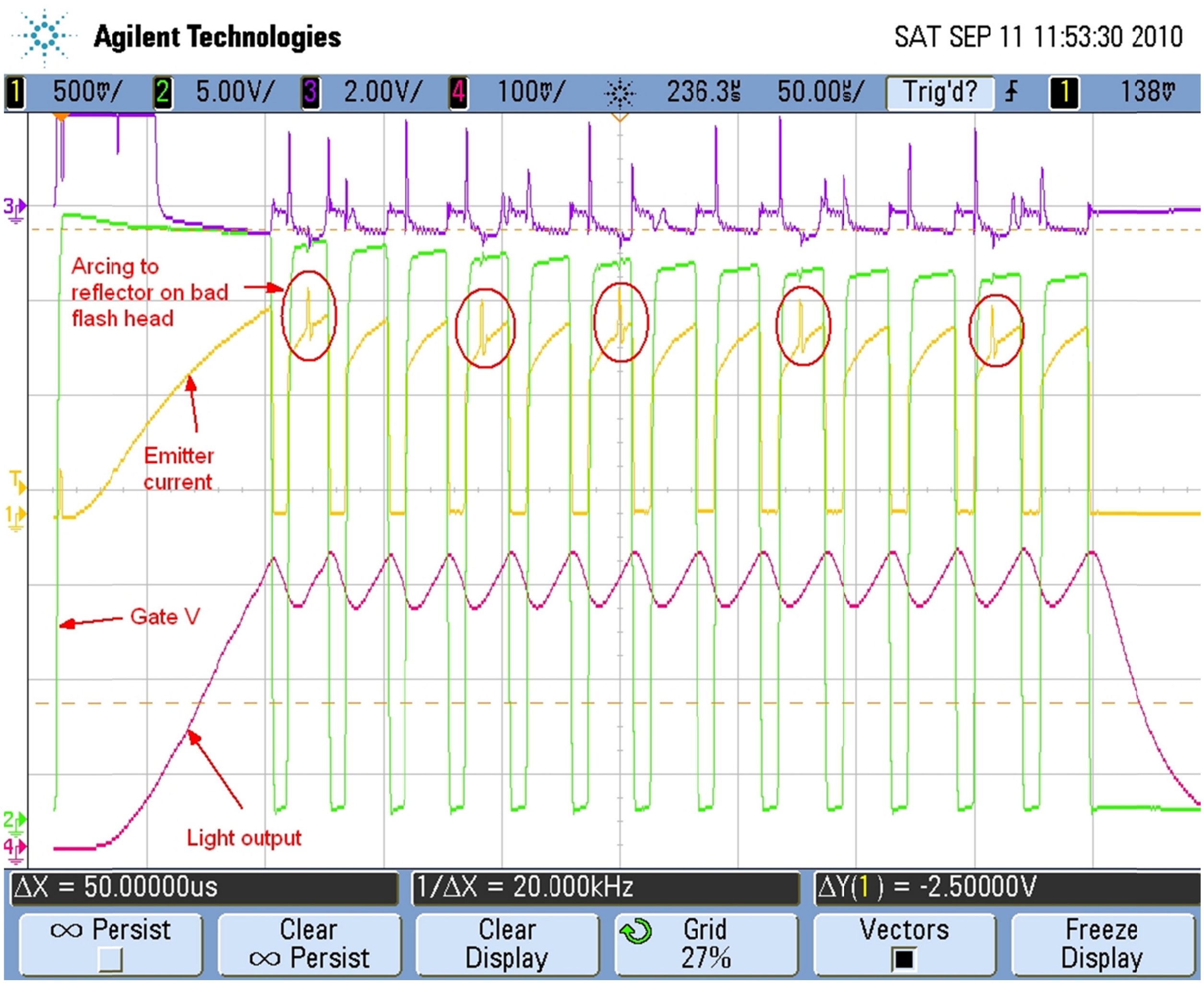

Figure 8: Short current spikes on IGBT emitter caused by arcing to reflector or trigger ring.

Note: Top trace is the control line going to the trigger coil driver circuit.

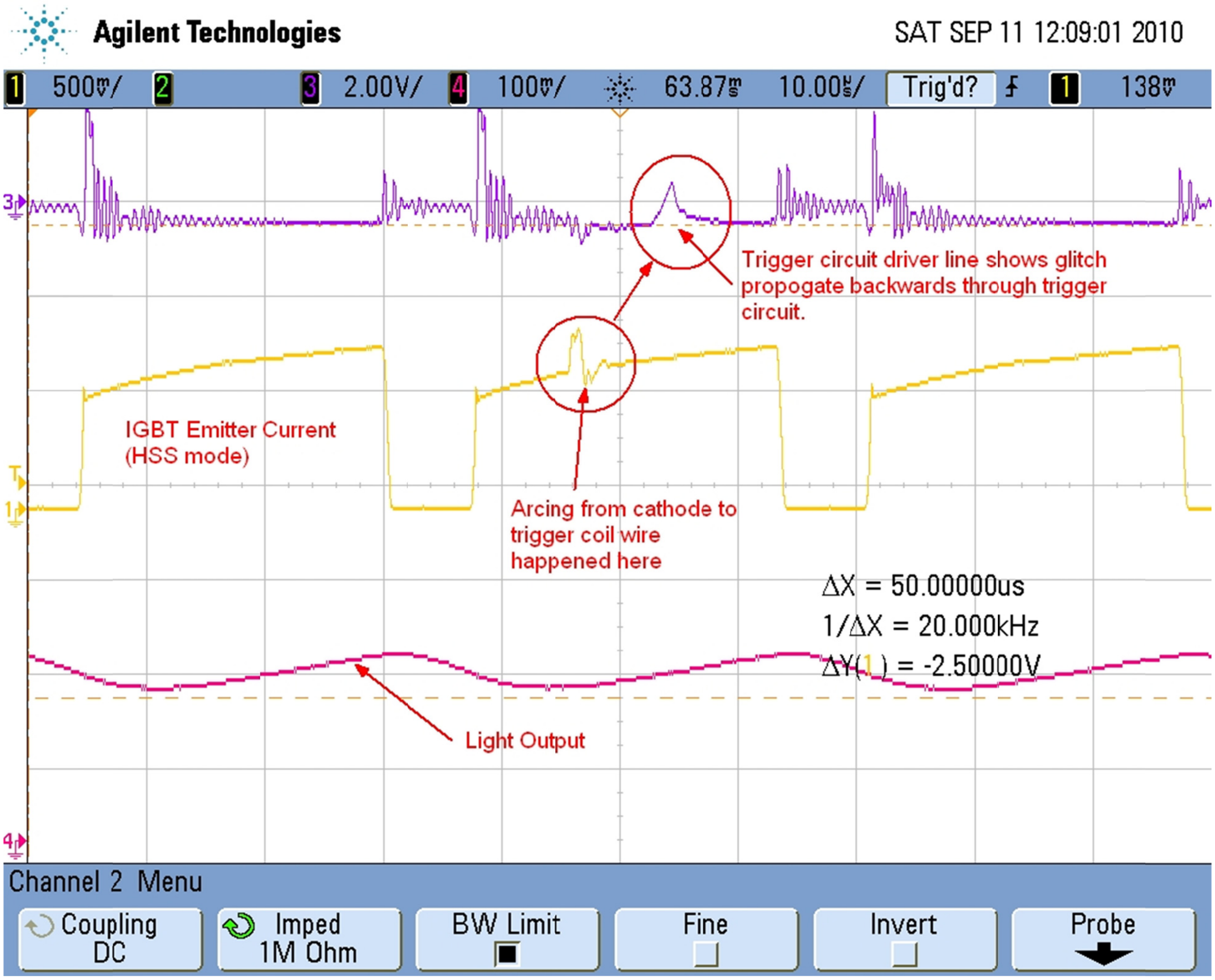

Figure 9: Same as Figure 8 (zoomed in) Short current spikes on IGBT emitter caused by arcing.

Note that the arc pulse to the trigger ring in this case propagates backwards through the trigger coil circuits. (Happens after arc not before which indicates that the control signal did not cause the arcing.)

In theory this figure 9 shows that the flashes electrical control circuits did not cause the trigger coil to fire at the moment that is circled above. <u>This also indicates that it's not a CPU firmware driven event that caused the arcing.</u>

To further confirm that this is in fact arcing to the trigger ring, we placed a 47K ohm resistor in series with the trigger ring and saw a significant reduction in current ringing on the circled event above as well as elimination of the circled pulse on the driver circuit line (top trace).

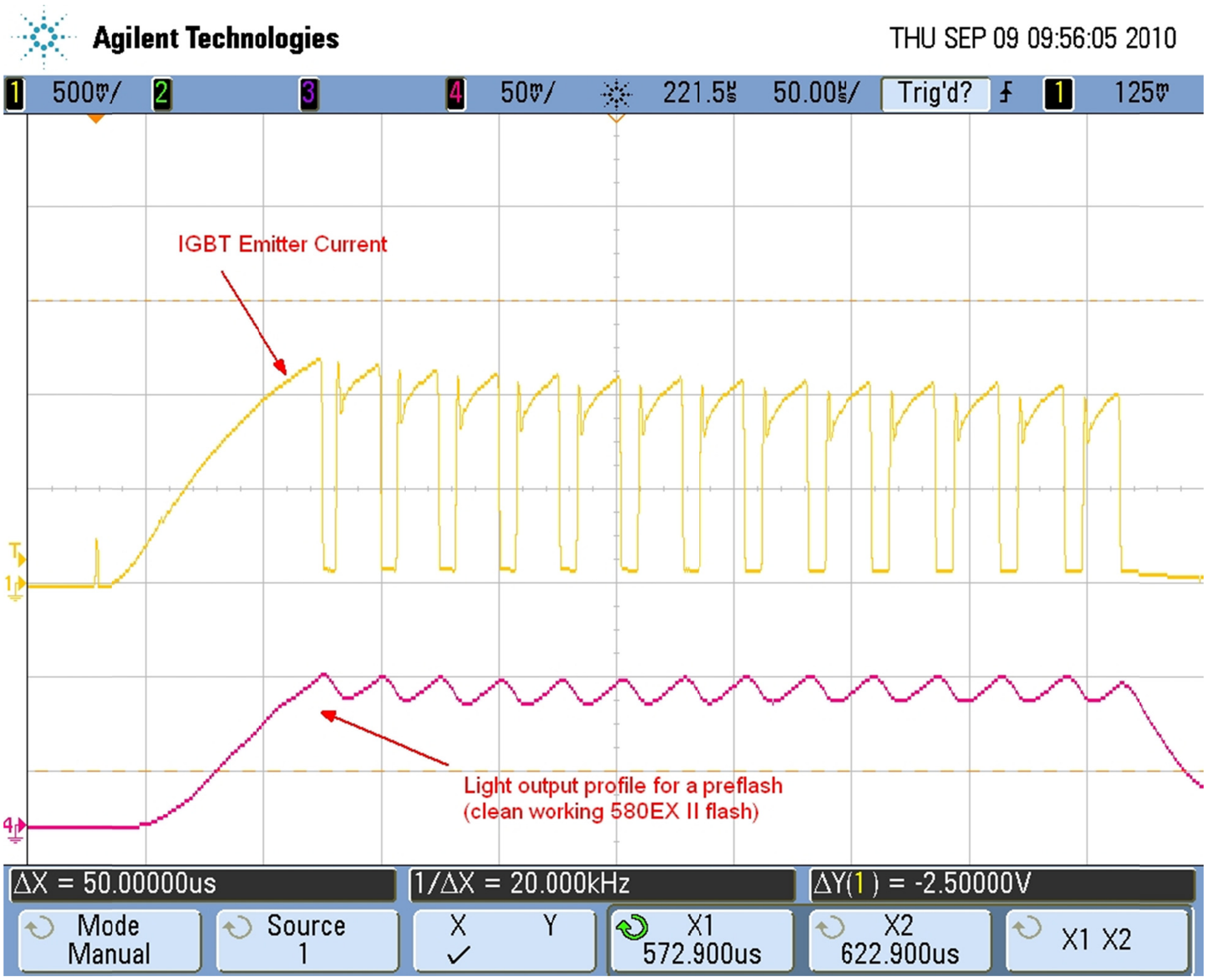

Figure 10: Typical trace showing a pre-flash (while using a PocketWizard MiniTT1 / FlexTT5) to trigger the 580 EX II on a good working flash that does not damage IGBTs.

Note that the current profile does not have any spikes in the middle of the IGBT ON periods.

This flash has a good positioning of the fiber optic and no signs of kinks or bends in the fiber.

Flash Tube Alignment:

Another significant observation is that flashes that have the flash tube aligned with the trigger ring extending into the reflector are more prone to fail again.

One theory is that this tube trigger ring positioning (top image) makes the spark gap distances to the metal reflector the shortest thereby enabling arcing to happen much easier.

Manually moving the flash tube shown on bottom image to the right such that the spark gap was shortened did increase the rate at which arcing occurred. (However it did not cause the IGBT to fail)

We have found that we cannot get the IGBT to fail if the front glass cover is not in place.

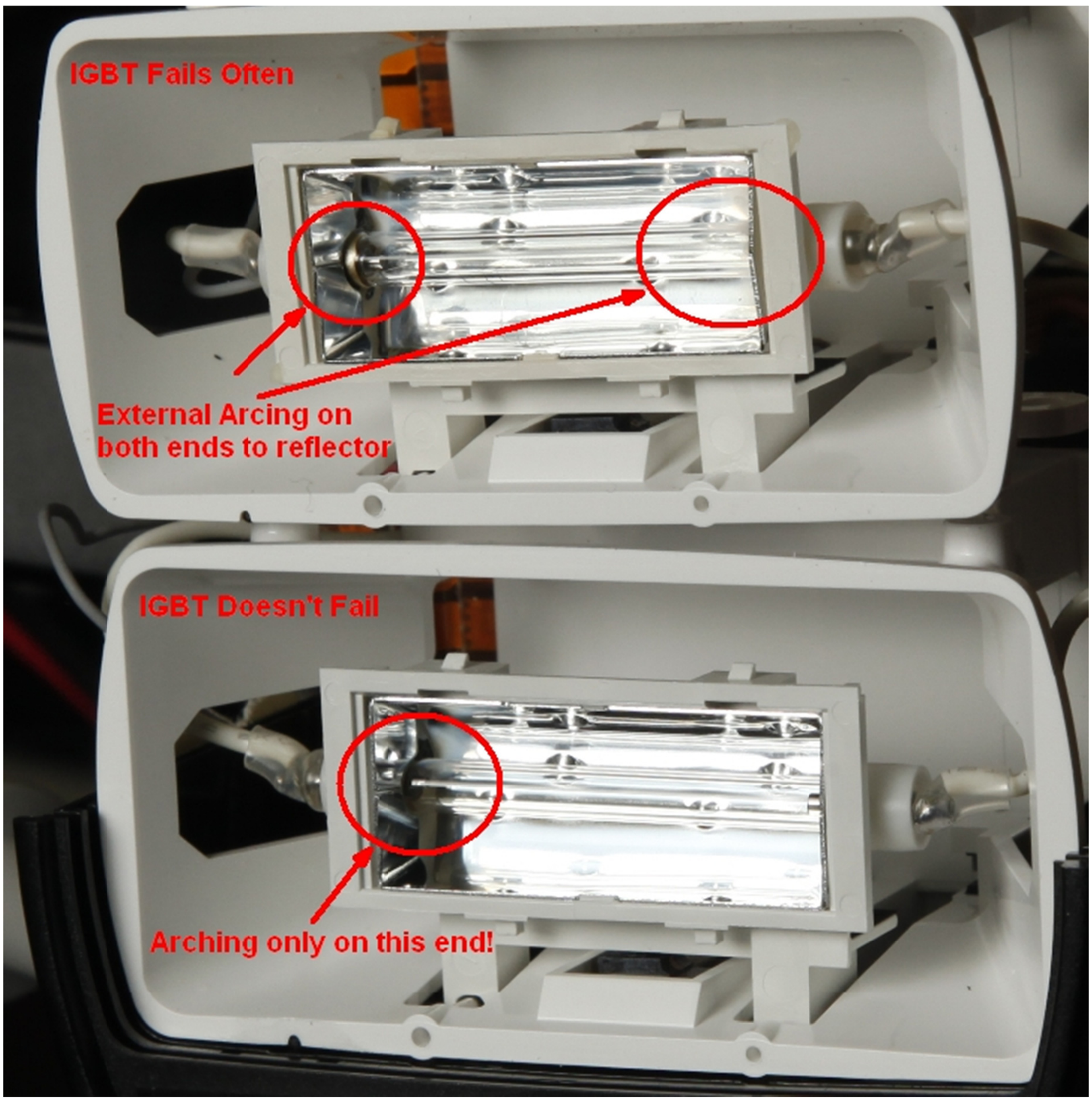

Figure 11: NOTE: the sealed glass covers are removed from the head assemblies for easier viewing of the flash tube.

Ozone from UV and Electrical fields:

Ozone is generated by using UV light, high voltages (10-20KV) or an electric spark (corona).

(source Wikipedia)

> It can also be prepared by applying 10,000-20,000 volts DC to dry O_2. This can be done with an apparatus consisting of two concentric glass tubes sealed together at the top, with in and out spigots at the top and bottom of the outer tube. The inner core should have a length of metal foil inserted into it connected to one side of the power source. The other side of the power source should be connected to another piece of foil wrapped around the outer tube. Dry O_2 should be run through the tube in one spigot. As the O_2 is run through one spigot into the apparatus and 10,000-20,000 volts DC are applied to the foil leads, electricity will discharge between the dry dioxygen in the middle and form O_3 and O_2 out the other spigot. The reaction can be summarized as follows:[6]
>
> $3\ O_2 \text{ — } \textit{electricity} \rightarrow 2\ O_3$

In a sealed container (such as sealed flash head) ozone can build up to dangerous levels and reduce the electrical breakdown voltage of air such that arcing (electrical discharge) can happen much easier at shorter distances.

Ozone can be generated in the presence of UV from flash tubes. However it's far more likely to be generated in the presence of rapid repeated electrical discharge. Pulsed high voltage electrical charge separated by a glass tube is how commercial / industrial ozone generators work.

High Speed Sync mode (HSS) of the 580EX II generates a lot of repeating pulses of electrical arc / discharge in a head that has a misaligned tube along with improper feedback from the fiber optic cable.

In theory this generates higher and higher levels of ozone that can't escape the head assembly.

The head assembly on the 580EXII has a glass cover over the front and a rubberized seal on both ends that hold the flash tube in place. The ozone has nowhere to go.

LPA Design theorized that ozone build up in the flash head is causing the failure events that ultimately damage the IGBT.

To further test this theory, we removed the glass front cover from a flash head assembly that typically did cause IGBTs to fail. With the glass cover removed, we can't get the IGBT to fail.

So in theory the best way to help prevent ozone build up is to ventilate the head assembly.

With these theories in mind, LPA Design rented an Ozone Gas Analyzer from Ozone Solutions.

(Model # 106-M) The model 106-M reads Ozone as low as 10ppb (10 parts per billion).

Pictures of the test setup are on the following page (Figs 12, 13).

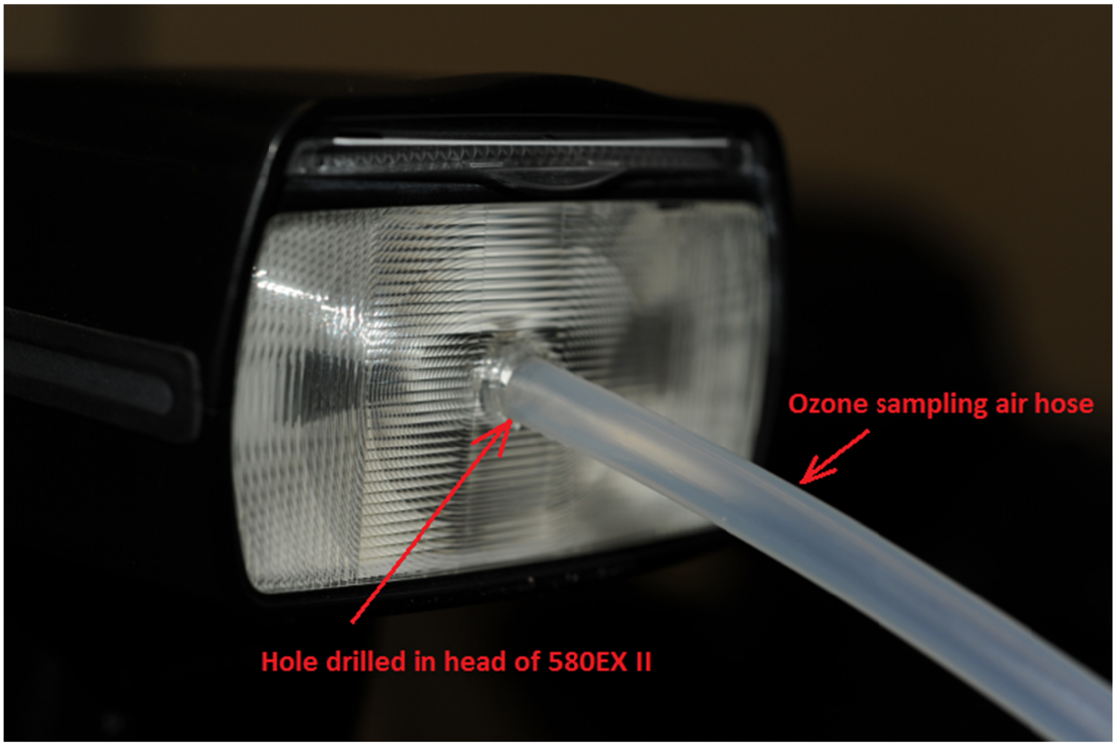

Figure 12: This 580EX II had the glass cover removed from the internal flash head assembly so that Ozone gas could be sampled via the front of the housing through the plastic Fresnel lens.

Figure 13: Ozone Solutions Gas analyzer model 106-M

Ozone Analysis of the 580EX II Flash:

Our first test was to confirm we could detect Ozone. To do this we removed the glass cover plate that seals the flash tube head assembly inside the flash head. We then set the camera that was connected to the flash via an OC-E3 cable to fire at 1 second intervals for about 40 seconds.

We confirmed that Ozone was starting to be detected. The Ozone analyzer samples air at a rate of 700ml per minute. In order to enable air to be drawn from the flash head, we had to drill a tiny air vent hole in the far back of the flash head near the pivot/hinge.

Next we moved the 580EX II flash to be off the camera running via its own optical trigger input. We set the flash to fire specifically 80 pops at 1.5 second intervals at maximum power at 1/8000th shutter speed (HSS mode). A Canon CP-E4 battery pack had to be used to enable firing this fast.

The Ozone analyzer has a voltage output port that was connected to an oscilloscope to show the build-up of ozone vs. time. The Ozone analyzer takes samples of air every 10 seconds and outputs a new reading after averaging for each 10 second period.

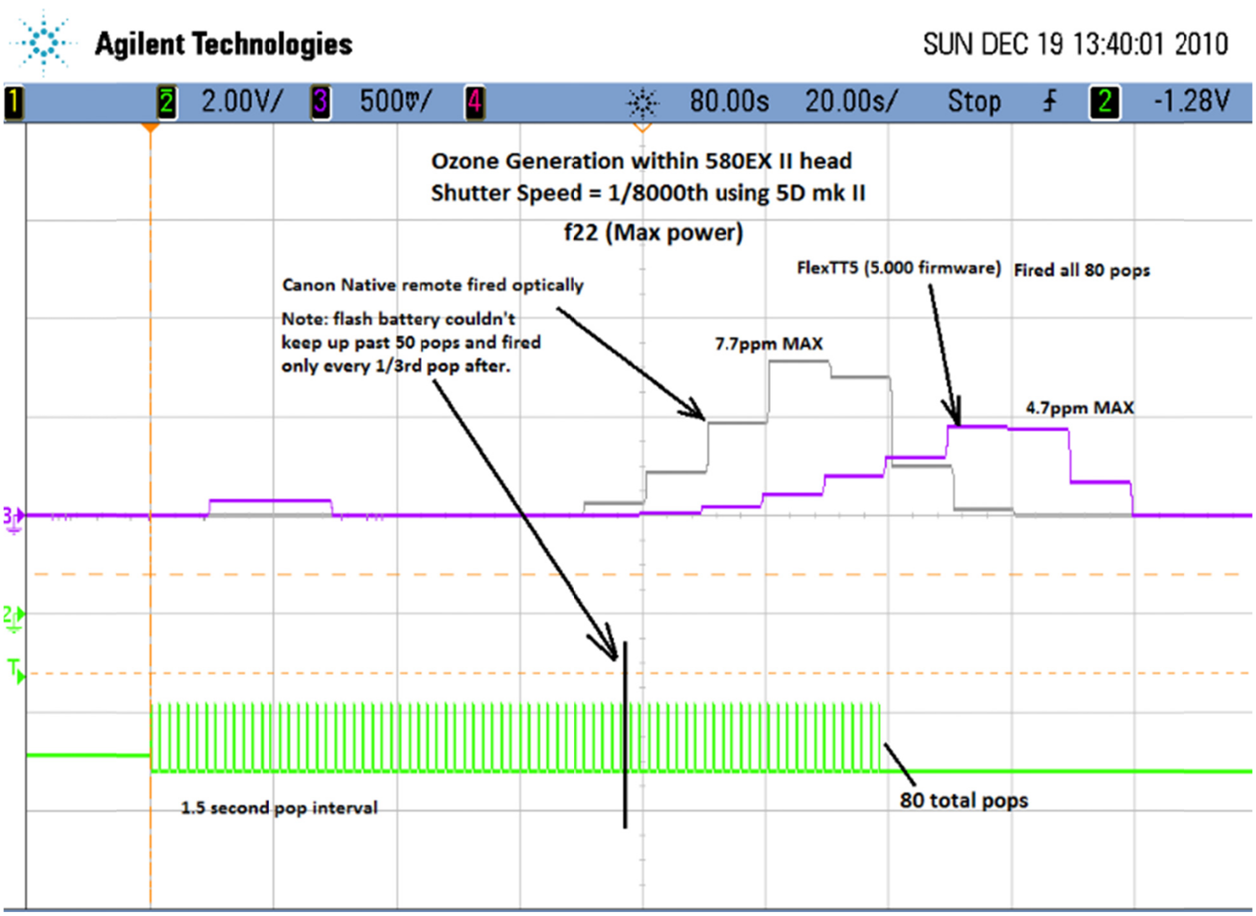

Figure 14:

As can be seen in the scope traces shown in Figure 14, the Canon native system using their own optical triggering has a much faster buildup of Ozone inside the flash head than when the PocketWizard FlexTT5 is used as the trigger. This lower rate of ozone buildup is likely related to the much more energy efficient HSS timing control system used by the PocketWizard ControlTL system.

Shown below (fig 15) are the two light pulse outputs as measured by a Thor Labs DET36A light sensor.

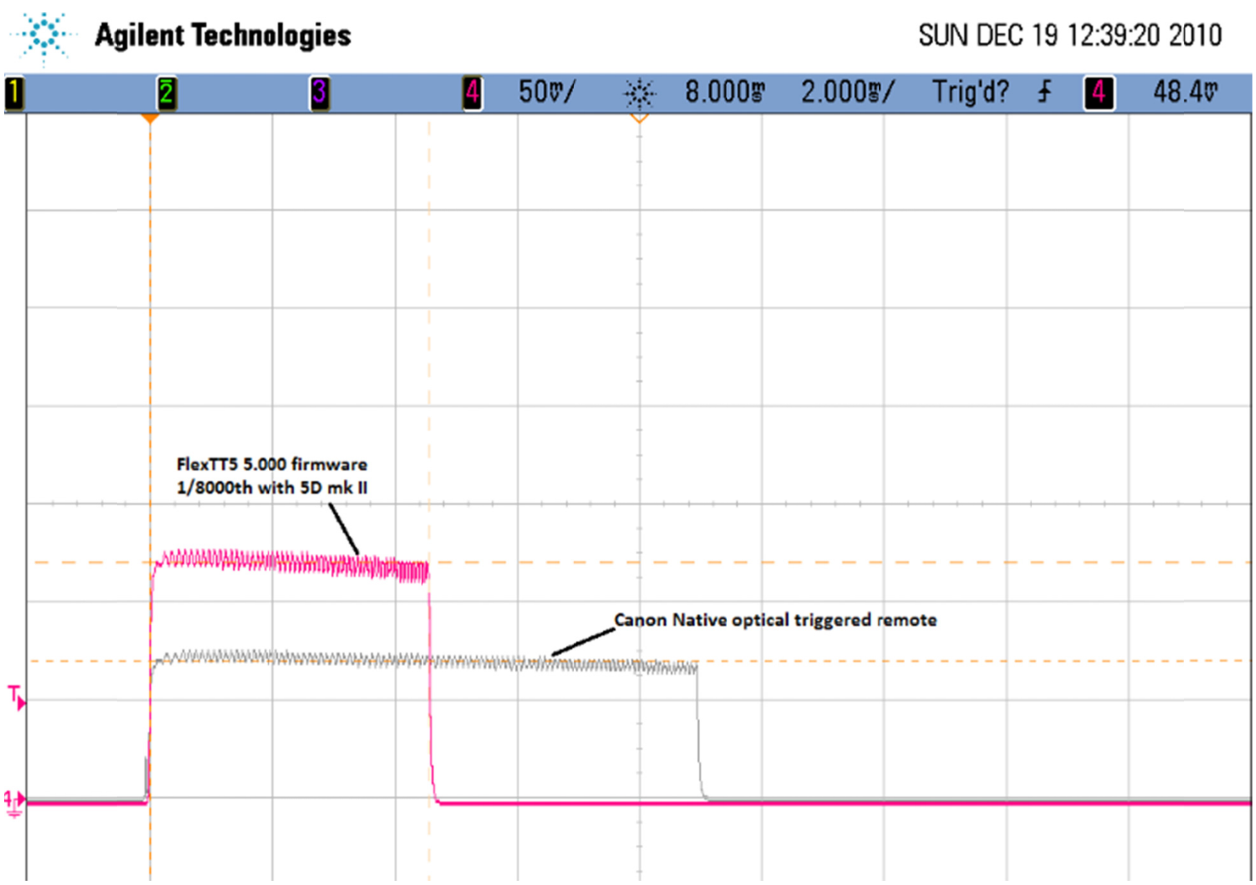

Figure 15: Showing full power HSS light output from 580EX II when fired via Canon's native optical control system. The red trace shows the shorter firing time but brighter maximum output that is possible when using the PocketWizard FlexTT5 as the triggering system.

Since the light output when using the PocketWizard radio was brighter but half the duration, the total energy that was delivered by the flash tube was the same but the resulting ozone buildup inside the flash head was half as much when using the PocketWizard FlexTT5.

Our theoretical conclusion is that the rapid firing of the 10KV trigger circuit repeatedly inside the 580EX II is what causes most of the ozone buildup and not the brightness of the light output.

To further confirm this, we also fired a long series of non-HSS full power light pulses for comparison. (see Figure 16 on following page)

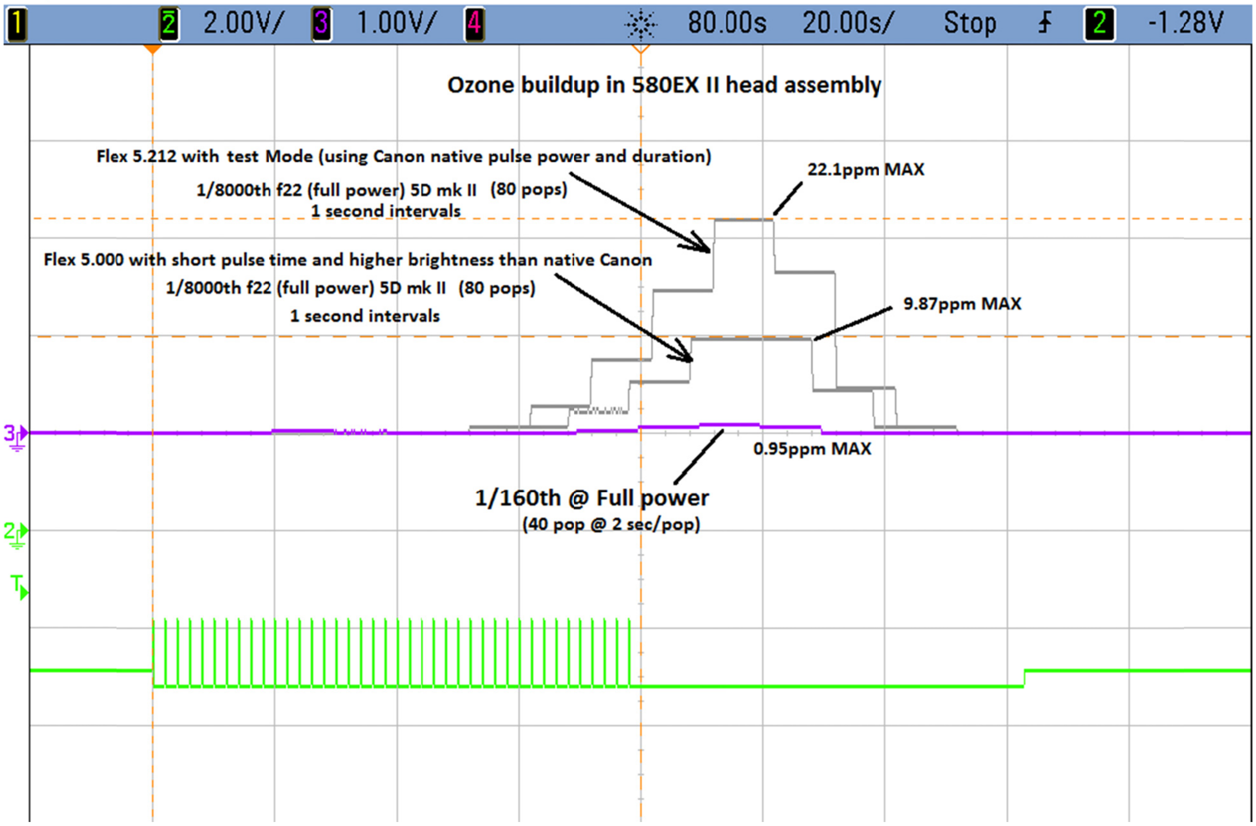

Figure 16: When firing the flash using only a full power dump in non-HSS (below X-Sync) the ozone buildup was nearly zero. However when we tried to duplicate the exact same pulse duration and brightness of Canon's native optically triggered HSS (1/8000th) the ozone buildup was much greater.

Test mode in FlexTT5 firmware 5.212 (never a public release) was to test our theory that duplicating Canon's native pulse duration and brightness of their optical ETTL system might be less prone to having the IGBT fail. We had thought that perhaps the brighter light output capability of the PocketWizard system might have increased the chances of a failure event.

However the tests did not have that outcome. We found that the 10KV electrical pulses from the trigger ring around the flash tube were likely the more significant cause of the ozone formation and not the UV light emitted by the flash since a longer duration HSS pulse has many more firings of the trigger ring. A full power non-HSS flash pulse is far brighter and yet generates nearly zero ozone. This full power non-HSS pulse has only a single firing of the trigger ring on the flash tube at the beginning of the light output.

We are preparing to run tests at the University of Vermont (UVM) in the coming weeks to find out how much the ozone will change the electrical breakdown of air such that an electrical spark will jump from trigger ring to the reflector metal housing. Chemistry professor Giuseppe Petrucci of UVM is a researcher in the field of ozone and will be assisting us to further our research and theories.

Preflash Boost:

PocketWizard introduced back in April of 2009 a firmware feature that enables a brighter preflash to be selected by the user. The default was to have the brighter preflash enabled.

In September of 2010 as part of our on-going research into this IGBT failure problem in 580EX II flashes, we tried a test where we changed the default of the preflash to be disabled.

After 5 months of collecting data since defaulting to preflash boost OFF, we have found there was no change in reported failure rate since. In fact, the preflash boost was confirmed to be disabled in most of our recent reports.

Our current conclusion so far is that the Preflash Boost feature is not related to the 580EXII's IGBT failure.

An important thing to note is that Canon's preflash is a short form of HSS. It is just a 400us long HSS pulse. So a preflash can generate a quantity of the high voltage pulses similar to the HSS main flash mode. So even if a user is shooting at or below X-Sync with non-HSS exposures, the preflash may still be generating ozone.

Further tests will be needed to determine if preflashes alone could generate enough ozone to cause the failure even if we disable any main exposure light output.

Other testing:

We conducted many experiments around heat, static, and other factors.

Using an ESD generator, we discharged 11,000 – 20,000 volts into many places on a 580EX II both alone and mounted on a FlexTT5 with and without the AC5. No issues were noted. The 580EX II and FlexTT5 are both CE marked products which means they must be able to handle a certain level of ESD to qualify for sale in European countries.

Heat tests over long periods, "torture tests" of hundreds of triggers in various configurations, and electrical short tests on the shoe pins were conducted.

None of these tests yielded any repeatable failure modes or conclusive data around IGBT failure.

The 430EXII does not damage IGBTs.

As part of the research efforts we also wanted to review a few other flashes and look at how they were designed. The newest 430EX II flash from Canon is one that is working extremely well and reliable for people. While we have had a single failure report, the flash was not sent to us and we could not confirm the failure was actually related to an IGBT or if it had any relation to ozone. Since this one failure occurred right after initial purchase, it may have been a manufacturing defect.

The Canon 430EX II Flash Head Assembly:

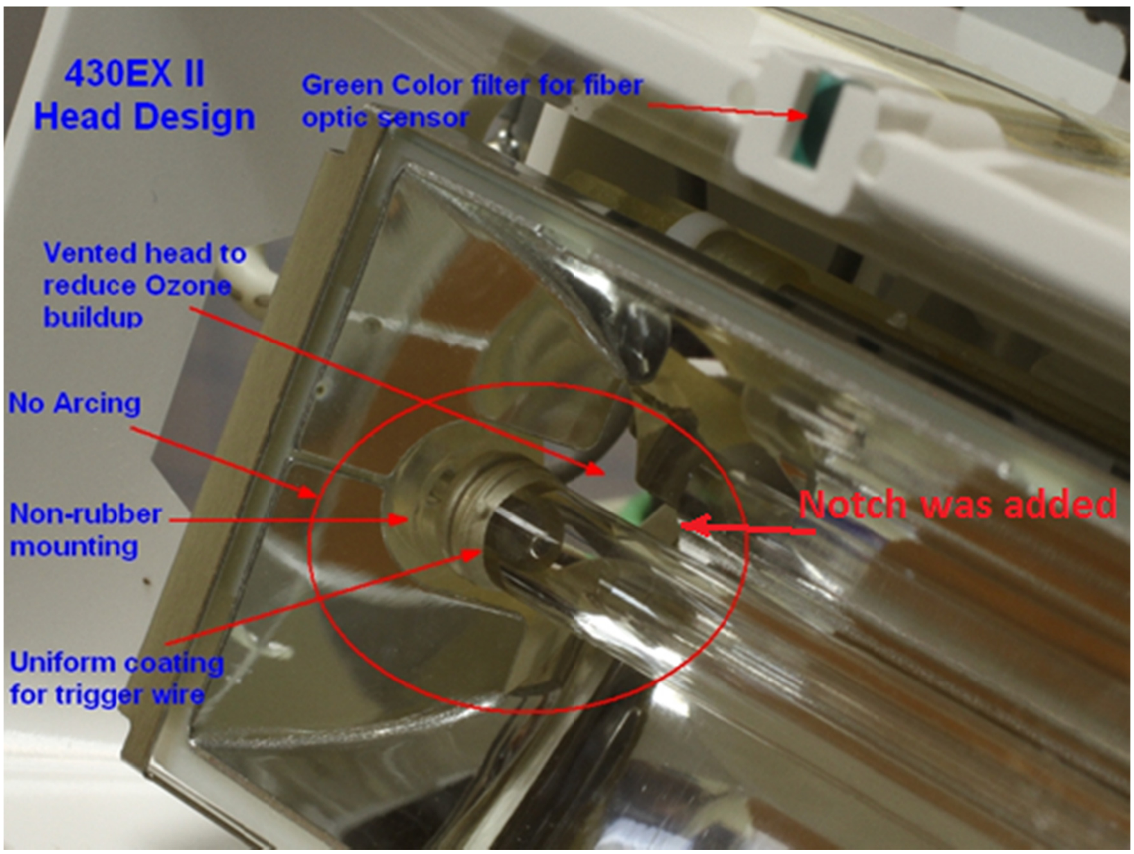

Figure 17: The 430EX II has 3 times more air gap space between the trigger ring wire and the metal reflector than used in the 580EX II. Additionally, a cutout was added directly below the flash tube theoretically for extra venting and clearance from electrical arcing.

The rubber end seal & mount used on the 580EX II is eliminated on the 430EX II.

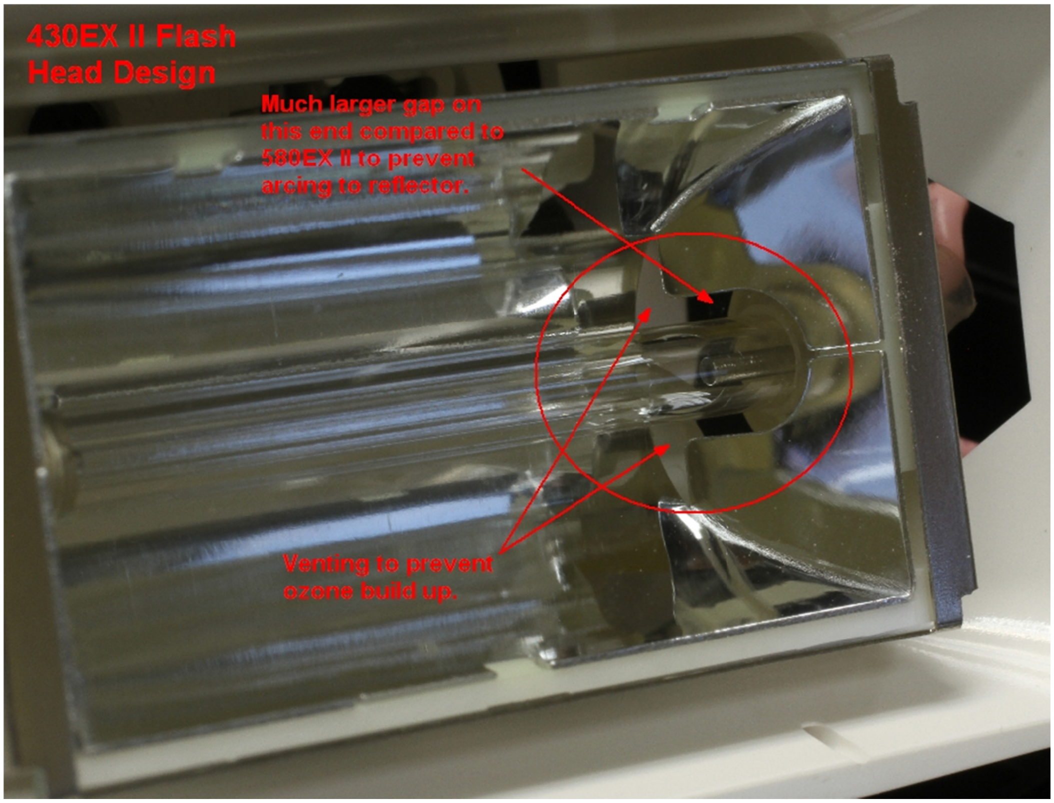

Figure 18: The 430EX II does not use a sealed end cap to hold the flash tube in position like the 580EX II flash uses.

The 430EX II was designed and started shipping before PocketWizard ControlTL products existed.

It has become LPA Design's theory that design problems with the 580EX II were realized and needed improvement of the design on these elements to prevent failures of a similar nature on future flash models.

The older Canon **580EX** flash does have a head design that is somewhat similar to the 580EX II, except that the flash tube is held in position directly by a printed circuit board and has no way for the flash tube to get accidentally aligned in the wrong position by hand assembly workers at a factory. Also, the optical feedback sensor in the 580EX is very different and may be less susceptible to hand assembly problems.

Conclusions: (The Perfect Storm)

It appears that some combination of elements comes together to create the risk and increased probability of an IGBT failure within the 580EX II.

- Sealed flash tube assembly (internal zoom carriage assembly)
- Misalignment of the flash tube within the reflector such that arcing is more probable
- Reduced optical feedback via the fiber optic sense cable in the flash head
- Dryer air where ozone can be generated more easily
- Electrical discharge through the reflector at a moment when the IGBT is turned off

By reviewing heavily used 430EXII flashes (Canon's newest) and seeing no signs at all of arcing within the reflector or on the flash tube, we have theorized that possible 580EX II design issues were corrected by identifying the same problems discussed in this document and changing the design to minimize the potential for damage on the newer 430EX II flash.

PocketWizard markets and encourages people to get out and use high speed sync (HSS). We make it easier than ever before for larger numbers of flashes to be used in these modes since our system does not have limitations in bright sunlight conditions compared to optically triggered Canon flashes.

We believe that HSS flash mode is more prone to have failure but is not a requirement of failure to happen. Some combination of TTL Preflash and or HSS main flash seems to be required.

Our ControlTL firmware controls the brightness in for a 580EX II in HSS mode to no more than what is permitted by the Canon 40D, 50D, 7D series cameras which have the shortest HSS pulse durations (when flash is on top of the camera) and therefore have the highest native permitted power request levels. These cameras have the shortest blade travel times for their shutters.

Our Pre-flash boost mode does not increase the chances of a failure since equal numbers of people have had a failure with it disabled as have had it enabled. Our AC5 and AC7 shielding products were not even used in about 50% of the reported failures and did not even exist when first reports of failures started.

So while PocketWizard products do not appear to cause the failure, through aggressive marketing of remote HSS features of Canon's flashes we may be accidentally contributing to the rate in which failures happen.

Research will continue in trying to find solutions (if any) to reducing the risk of failures on the 580EX II.