Laser Cutting of Pressed Explosives*

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We have used a femtosecond laser beam to make cuts through small pressed pellets of six common explosives. The laser system, which produces 100 fs pulses of 820 nm light at a repitition rate of 1 kHz, was intitially developed for cutting metal. The advantage of using a femtosecond laser for cutting is that the cutting process transfers virtually no heat to the material that is being cut and produces almost no waste. We used LX-16 explosive (96% PETN/4% FPC 461 binder) for out intial experiments because PETN is one of the most sensitve of the secondary explosives. In some of the experiments the beam first cut through the HE pellet and then through a stainless steel substrate and in other experiments the beam first cut through the stainless steel and then through the pellet. We also cut through pellets that were not backed by a substrate. No evidence of reaction was observed in any of the LX-16 pellets. In addition to LX-16 we cut pellets of LX-14 (95.5% HMX/4.5% Estane), LX-15 (95% HNS/5% Kel-F), LX-17 (92.5% TATB/7.5% Kel-F), PBX-9407 (94% RDX/6% Exon 461), and pressed TNT with no evidence of reaction. The HE was easily cut at low power levels with one or two sweeps at 0.5 W average power sufficing to cut most of the pellets. There is obvioulsy much more work to be done before laser machining of explosives becomes a reality, but the results of these intitial experiments indicate that laser machining of explosives may be an attractive option for explosives processing.

1.0 INTRODUCTION

Current methods of cutting high explosives (HE) are limited because of safety concerns. These safety concerns arise mainly from the fact that conventional cutting techniques transfer heat to the explosive. If too much heat is absorbed by the explosive during cutting the explosive may react and, in some cases, could progress from a thermal reaction to a detonation.

Other problems with conventional cutting techniques is the hazardous waste stream that is created involving

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particles of HE. Dealing with the hazardous wastes adds expense and time to any HE cutting procedure.

Laser techniques provide a means to overcome these problems. An addition, laser cutting techniques allow more precision cuts and machining of geometries not allowed by conventional methods.

Some laser techniques, however, do not get around the problems of heat transfer and, because of this require complicated procedures for cutting both metals and HE in the same machining process. Using femtosecond laser pulses to cut HE and metals show evidence that we can avoid all of the problems associated with conventional cutting means and other laser cutting techniques.

2.0 EXPERIMENTAL

The laser system produces 100 fs pulses of 820 nm light at a repetition rate of 1 kHz. We used a laser footprint of 300 µm x 25 µm, with the cutting direction in the direction of the 300 µm. A spot was used for the hole-drilling experiments and the spot size varied from 25 µm to 250 µm. Average power levels used were from 0.1 to 3 W.

Explosives were cut in a 2-g firing chamber (fig. 1). A vacuum is required to propagate the laser beam as it is focused down and also greatly increases the safety margin of the chamber, which is rated for 2 g of HE with atmospheric pressure inside. Vacuum levels used were from 30 to 150 Torr. The laser beam entered the firing chamber through a quartz window and was swept back and forth across the sample by means of a mirror. The back side of the sample was monitored through another quartz window by a video camera connected to a VCR. This allowed us to determine when the beam cut all the way through the target.

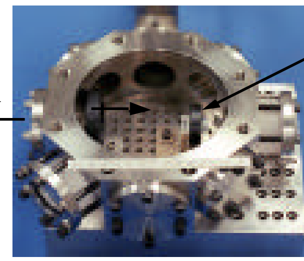

Figure 1. Portable firing chamber shown without the steel lid in place.

The samples were 6.35-mm-diameter, 2-mm-thick, pressed pellets of various explosives mounted on stainless steel substrates whose thickness ranged from 0.1-1.2 mm.

3.0 RESULTS AND DISCUSSION

We used LX-16 explosive (96%PETN/4% FPC 461 binder) for our initial experiments because PETN is one of the most sensitive of the secondary explosives. In some of the experiments the beam first cut through the HE pellet and then into the stainless steel substrate and in other experiments the beam first cut through the stainless steel and then into the HE pellet. In either case, no reaction was observed in the LX-16 pellets. Figure 2 shows a cross section of a LX-16 pellet that has been cut. We also cut through pellets which were not backed by a substrate. In addition to LX-

16 we cut pellets of LX-14 (95.5% HMX/4.5% Estane), LX-15 (95% HNS/5% Kel-F) fig. 3, LX-17 (92.5% TATB/7.5% Kel-F), PBX-9407 (94% RDX/6% Exon 461), and pressed TNT. HMX and RDX are high-performance explosives used in many types of explosive ordnance, PETN and HNS are initiating explosives, TATB is an insensitive explosive and TNT is ubiquitous in conventional ordnance.

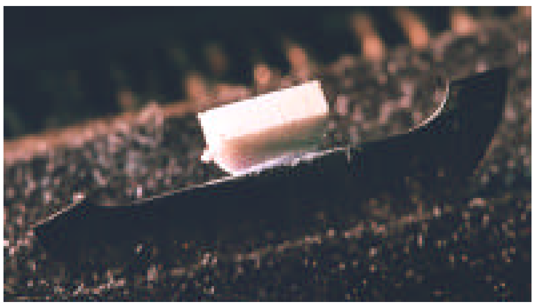

Figure 2. Cross section of an LX-16 pellet. The other half is not shown. The pellet is glued to a stainless steel substrate.

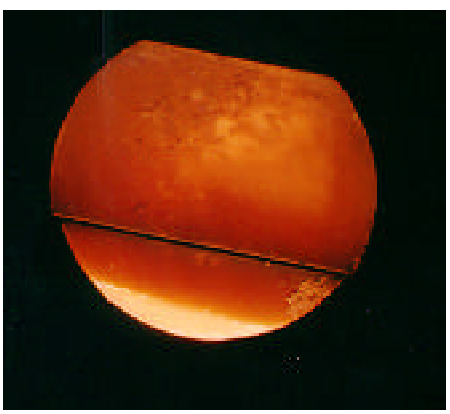

Figure 3. Femtosecond laser cut in LX-15.

The HE was easily cut at low power levels. At 0.5W average power, one or two sweeps sufficed to cut most of the pellets. The LX-14 required more sweeps than the other HE materials. No reaction was observed in any of these materials. In the experiments where the pellets were cut on a stainless steel backing, the metal plasma produced discoloration of the pellet surface, particularly when the cuts were made through the pellet into the metal substrate. When LX-16, LX-14 and PBX-9407 were cut without the stainless steel backing, the cut was clean with no discoloration or other visible evidence of reaction but the TNT, LX-15 and LX-17, which have solid carbon in their reaction products, showed some soot deposition on the cut surfaces. The only experiment in which a reaction was observed was with a LX-16 pellet when we lengthened out the pulse to 0.5 ns (a factor of 5000). Figure 4 shows the cut made with the long pulse.With the long pulses, 10 sweeps at 1W average power barely marked the surface of the pellet, but with a single sweep at 3W, the video record of the experiment appeared to show material reacting, and examination of the pellet afterward revealed that the edges of the cut were melted, although the pellet was still intact. It is clear that ultra-short pulses are essential to laser cutting and machining of explosive materials.

The reason we can sucessfully cut with an ultra-short pulse and not with longer pulses is that the energy from the femtosecond pulse is absorbed in a shorter time than it takes for a lattice vibration in the material being cut to occur. Since heat is transferred by lattice vibrations, virtually no heat is absorbed by the material. The hot plasma created expands and rapidly cools trasferring very little heat to the material. A shock wave is created by the laser pulses but is too brief to cause any significant reaction.

Figure 4. LX-16 cut with a long pulse (.5 ns). Definite signs that a reaction may have occred are visible.

We have also shown that the femtosecond laser pulse will cut almost anything. In addition to the metals and explosives, we have cut aerogel material, ceramics and even diamond.

4.0 CONCLUSIONS

We have demonstrated that the femtosecond laser cutting technique is an attractive option for use in demilitarization or precision HE machining operations.

The laser ablation takes place on a much shorter timescale than thermal processes and therefore makes this technique superior from the safety standpoint. No solid HE waste products are formed thus making the process potentially less expensive (and also safer) than conventional cutting techniques. The laser can be used for precision cutting that is superior to other existing methods for machining HE.