Appendix B

Description of Laser Entertainment Events

B.1 Outdoor Classical Laser and Fireworks Concert A

B.1.1 Introduction

The grounds of a stately home were used to stage an outdoor charity classical concert accompanied by a fireworks and laser display. The laser company, Company A, had submitted the appendix to the HSE Guidance, PM19 (HSE 1980), for approval to the licensing authority, the local District Council Environmental Health Department. The author attended the event at the invitation of the Environmental Health Department because they felt they had insufficient expertise to assess the laser safety.

The audience consisted of about 2000 people who sat either on the grass or brought tables and chairs with them. Many members of the audience were treating the event as purely social and, unlike a performance in a theatre, it could not be assumed that they would necessarily have been looking at the stage. A significant proportion of the audience were consuming alcohol during the performance.

The fireworks display was positioned well behind the stage and appeared to be carried out in a very professional manner. The fire brigade were present and did show a passing interest in the safety aspects of the laser display.

B.1.2 Details of Laser System

Three class 4 lasers were used. The layout of the lasers is shown in figure B.1. Although the original paperwork stated that there would be two Spectra Physics 168 argon ion lasers and one Coherent Purelight argon/krypton laser, there were three argon ion lasers on the day.

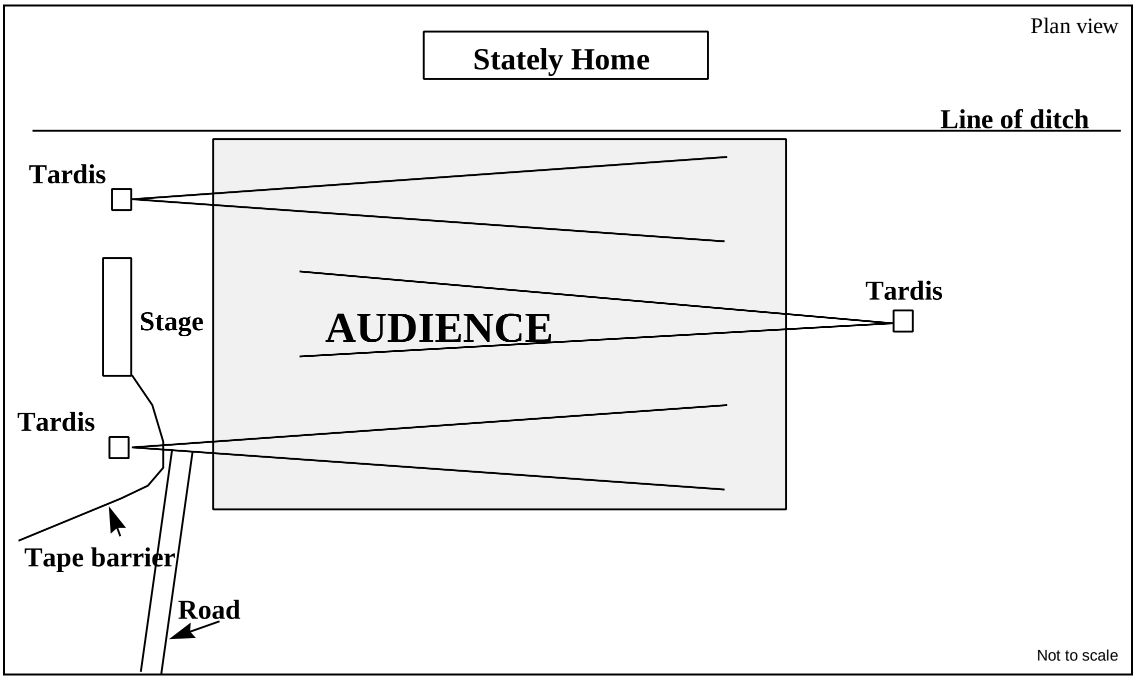

Figure B.1 Layout of Event A

The system used by Company A was claimed by them to be unique. The laser system, optics and control consoles were contained in a prefabricated ‘tardis’. This reduced the time required to set up the display. A schematic of the tardis is shown in figure B.2.

The laser show was controlled by the operator at the rear of the audience under directions from a member of the production company. However, there was no direct control of the two lasers beside the stage from this position. This was achieved under radio control to a second operator located in the stage right laser position. This second operator was able to control the two stage lasers from this position. The author was assured that a third person was actually close to the stage left tardis to terminate the laser should the need arise.

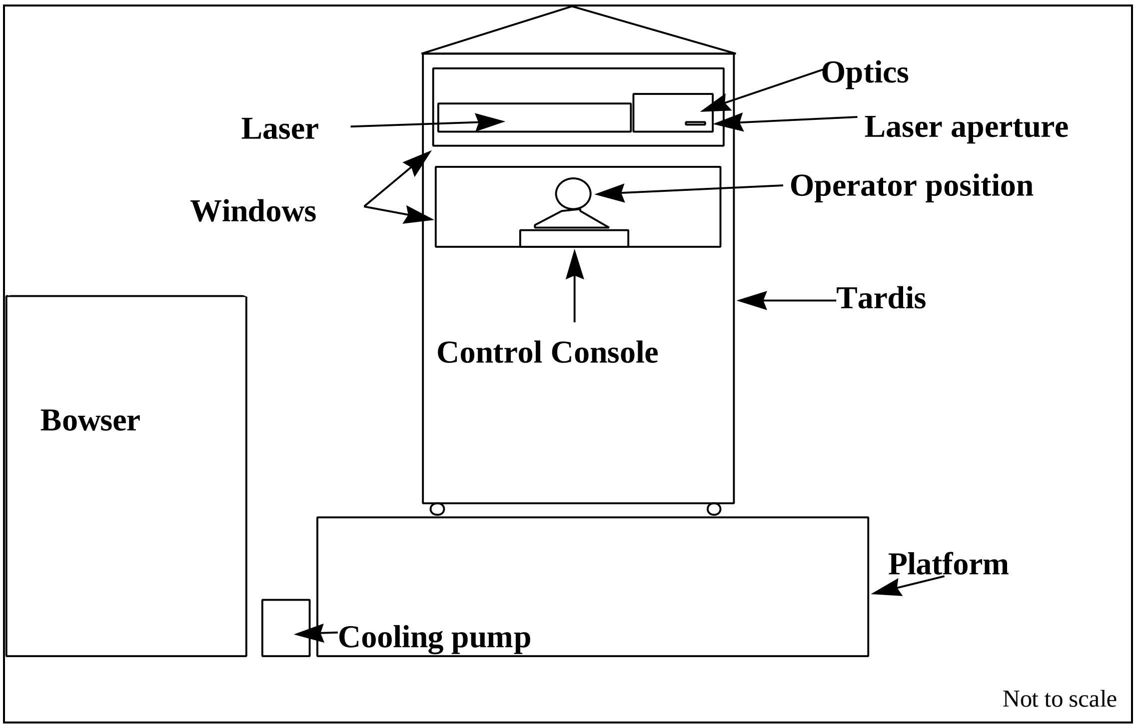

Figure B.2 ‘Tardis’ layout

Three-phase mains power was supplied from a generator located away from the lasers. This was supplied by the production company.

B.1.3 Problems Experienced

A plan of the site with the positions of the lasers marked on it was supplied prior to the event. The layout on the day was rotated approximately 45° counter-clockwise. This reduced the potential for the laser radiation to be directed towards the stately home but was fortuitous rather than planned.

The laser behind the audience was originally specified as being an Argon/Krypton of 2 W nominal output power with a beam divergence of 5.3 mrad. The laser used on the day was a 4 W argon ion with a beam divergence of 3.2 mrad. If the calculations of maximum permissible exposure had been critical from the original laser then, without a site visit, clearance could have been given for a situation that was potentially hazardous.

Company A were aware of the potential for eye injury should the laser radiation be directed into the audience. Measurements taken by the author confirmed that the maximum permissible exposure levels were unlikely to be exceeded on the stage. Masking panels (aluminium plates, painted matt black) were positioned to restrict the beam so that it could only be directed horizontally or at angles above horizontal. There was also an additional section of the blanking plate on the laser to the rear of the audience which blanked out the stage.

The tardis units were mounted on castors typical of the type used on transport cases by sound and stage engineers. The integral locking mechanism was the only means of fixing the tardis in place. The tardis was also mounted on a platform which was constructed on each site. The whole system was not stable and relied on the operator not carrying out any sudden movements.

The blanking plates were fixed in position with adhesive tape. This meant that they were vulnerable and could easily be accidentally moved.

Handheld radios of unknown frequency, but probably in the VHF region, were used to communicate between the operators. It was noted that the transmitters were capable of inducing sufficient current in the laser beam-positioning galvanometers to deflect the laser beam. This should not present a safety issue if the blanking system is effective, but does raise the issue of electromagnetic compatibility (EMC).

The lasers used were cooled by water held in bowsers. The water supply to fill the bowsers came from standpipes around the site. Each bowser took approximately 1.5 hours to fill with water. About 50 minutes prior to the performance commencing the operator noted that the bowser for the laser behind the audience was empty. The cooling water pump had been left running after an earlier test of the laser, the return pipe had fallen out of the bowser and drained the water. The human element then became significant. The operator and support team were now under extreme pressure to refill the bowser in what they knew to be less time than actually required. There was also concern over the state of the cooling water pump which had been running dry for an unknown time.

Sufficient water was put into the bowser by the start of the performance to allow the laser to operate. However, the pump bearings were leaking water adding to the concern of the operator. Just as the performance was due to start the operator realised that a cover, which had been placed over the front of the beam aperture to protect it from the rain, was still in place. This was hurriedly removed, probably disturbing both the position of the blanking plates and the tardis on the platform.

The beams from the rear laser were initially directed into the air, as planned. However, when the operator initiated some ‘screen writing’ onto the trees behind the stage, the beam was directed into the audience, approximately 20 m in front of the tardis. The operator acted quickly to get the beam up into the air.

The stage left laser did not operate initially and received attention from one of the Company A support crew. When the laser did eventually operate, the beam was low and a video recording taken at the time demonstrates that the beam was directed into the audience on a number of occasions. This may have been due to the blanking plate being moved or due to the tardis moving. It may also be significant that it had been raining all day and the ground was soft: the tardis may have been sinking into the ground.

B.1.4 Conclusion

Human elements played significant parts in the problems that were experienced with this performance. The laser company were aware of the hazards, although they were not able to quantify them, and appeared to be sincere about their desire to keep the beams out of the audience. Better engineering could have prevented most of the problems they experienced. An interesting problem here was the electromagnetic compatibility (EMC) issue where the radio interfered with the galvanometer. Proper screening of the optical system would have prevented such interference. However, it does raise the issue of other parts of the laser display system which could be subject to EMC problems.

The EHO was fully capable of assessing the electrical, mechanical and water safety of the laser display. However, he had no expertise of assessing laser radiation safety. The provision of plausible calculations of laser beam exposure conditions by the laser company caused some concern. When these were analysed in some details it was apparent that they did not relate to this specific event.

B.2 Outdoor Classical Laser and Fireworks Concert B

B.2.1 Introduction

The performance at this stately home was similar to that at Concert A except that the event was a commercial venture and a different laser company, Company B, were used. The invitation to attend came from the production company. The local Environmental Health Officer did not ask for any details of the laser display and no information was volunteered by either the production company or Company B.

Discussions prior to the event revealed that the laser company were not convinced that the laser radiation should be kept away from the audience. The show was a limited version of what they would normally do because of the author's presence. However, the laser operator considered that the audience attended such events in order to be 'irradiated by the laser'. No calculations were available to allow a judgement to be made on whether scanning the audience with the laser radiation would present an acceptable risk, both as intended and in the event of a failure condition.

The audience consisted of about 8000 people. The layout was similar to Concert A but was very cramped.

B.2.2 Details of the Laser System

Three lasers were used in a similar layout to the Concert A event. Each was stated as being 4 W nominal radiant power. The laser to stage right was an argon/krypton which was capable of being directed 360° around its position. The lasers were mounted on scaffolding which was constructed for each of the three laser positions.

Laser cooling was provided by a different means for each of the three lasers. The laser at the rear of the audience was cooled by water from a bowser. There was only one standpipe which was located close to the stately home. The site of the performance was on a slope rising away from the stage. This presented some problems with water pressure. The laser to stage right was cooled by water from the same standpipe but with continuous feed via a small reservoir. The third laser was cooled by re-circulating water from a refrigeration plant.

All three lasers were controlled from the position of the laser at the rear of the stage. This required a control cable to pass through the audience towards the stage.

B.2.3 Problems Experienced

The organisation of the laser company was less than ideal. They explained that they preferred to set up on the day before. However, since this event was being staged throughout the country and had been held the evening before across the other side of the country, the stage would not be in place until the morning of the performance. The stage is the key component of the show. All ancillary equipment, such as the lasers and sound systems are positioned relative to the stage. The generators for powering the lasers would also not be in position until the stage arrived.

The construction of the scaffolding towers and the installation of the laser and associated equipment took until early evening. The public had access to the site from about 6 pm with the music commencing at 7 pm: the lasers were due to start at 9.30 pm. Company B were not in a position to test the lasers until about 8.45 pm. This meant that the audience was essentially complete with about 8000 people present.

The operator claimed that the control optics always defaulted to a high elevation when switched on. This was proved to be erroneous because the beam was directed at the rear of the head of a member of the audience approximately 10 m from the laser. Although the operator reacted quickly to switch the beam off, the irradiance would have been sufficient for the risk of eye injury to have been high.

The operator carried out the alignment procedures on all three lasers and was under a high degree of stress because of the time limitation and the difficulty of moving through the audience to the other lasers. The laser control position to the rear of the audience was eventually surrounded by the audience. This encouraged a number of interested people to come along and ask questions of the operator.

When the show commenced a significant proportion of the effects involved irradiation of the audience. The author found the radiation from the stage lasers uncomfortable at about 100 m. Many members of the audience were being exposed at much shorter distances. The performance was recorded on video tape and the laser radiation often struck the camera lens.

Helium-filled reflective balloons were on sale during the event. Had the laser company been concerned with keeping the laser radiation out of the audience then these balloons, under some conditions, could have resulted in a potential exposure pathway for the audience. However, in general, such balloons would have resulted in an increased beam divergence for the reflected beam.

B.2.4 Conclusions

The attitude of the laser company towards laser safety gave some cause for concern. However, the Environmental Health Officer did not get involved and the production company did not seek any safety assurances from the laser company. Therefore, there was no external control over what the laser company were doing.

There was no blanking of the beam because the laser company did not consider this necessary. The admission by the laser company that the show had been sanitised slightly because of the author’s presence raises questions regarding the potential for eye injuries at events where this company is involved.

The laser company were able to produce sample calculations which purported to support the argument that the exposure of the audience to the laser radiation was at levels below the maximum permissible exposure. However, the calculations did not relate to the specific show given and certainly did not take into account many of the beam effects used.

B.3 Outdoor Display at a Marina C

B.3.1 Introduction

The laser display at a Marina was part of a Twinning Association event organised by the proprietor of the Marina. The author attended at the request of the local Environmental Health Officer since the District felt it had insufficient expertise to assess the laser radiation safety issues arising from the event. However, he was fully competent to assess the electrical and mechanical aspects of the event.

The laser was provided by Company C as a favour to the proprietor. The laser display was set up and operated by a freelance show designer.

The event was staged to raise money for the Twinning Association. Two German Minesweepers from the twin town were based at the Marina for the duration of the event. The proprietor had been on the local radio several times during the week to complain about the involvement of the Environmental Health Officer.

A public footpath passed through the site of the laser show and was the main cause for concern by the licensing authority.

B.3.2 Details of the Laser System

Two Coherent Innova 70 2 W argon ion lasers were mounted on piles at the marina. A control point was set up on the deck of one of the German Minesweepers.

The lasers were water cooled using water from standpipes located on the Marina. The mains transformers were mounted at the top of the piles close to the laser.

The layout of the site is shown in figure B.3 in plan. The proposed arrangement for the mirrors and laser beams is shown in figure B.4: the final arrangement is shown in figure B.5.

The laser operator was in radio contact with a sound engineer who was responsible for the recorded music to accompany the laser display. Four separate performances were planned: only three took place - see section B.3.3.

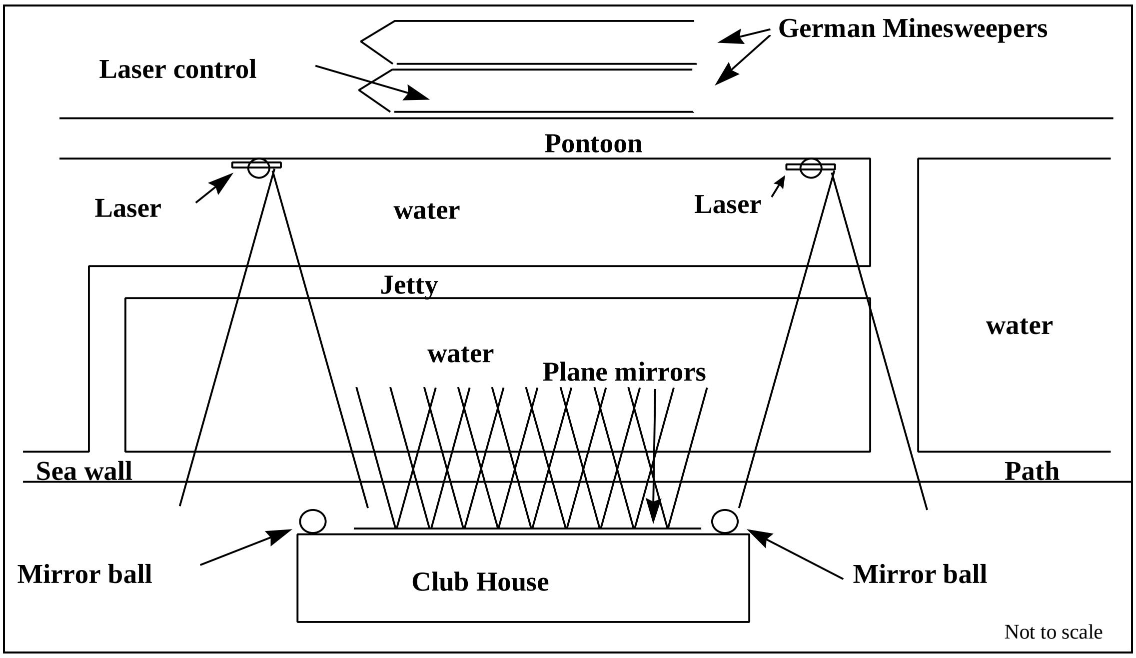

Figure B.3 General layout of Event C

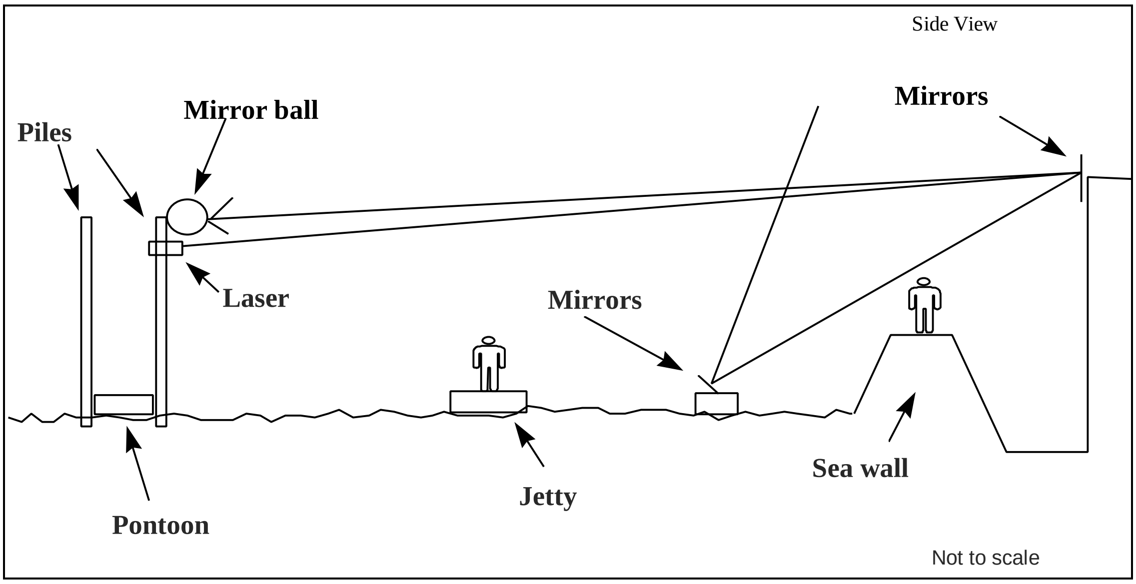

Figure B.4 Original Planned Layout for Event C

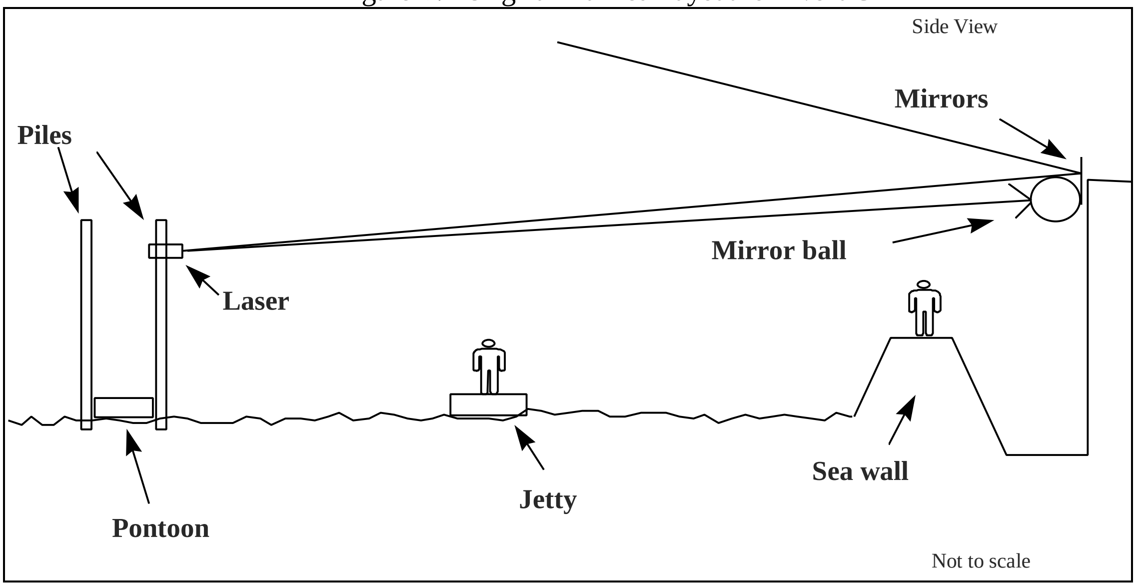

Figure B.5 Final Layout of Event C

A fun-fair was constructed during the days before the event. Some of the final components were constructed on the day of the event. The lasers and mirrors were installed during the evening prior to the event. All of the alignment was carried out during the night prior to the event.

B.3.3 Problems Experienced

The laser operator was aware that irradiating the audience with laser radiation was undesirable. Pressure from the Environmental Health Officer restricted the number of mirrors and the position of the mirrors to areas away from accessible areas.

During the day of the performance a helter-skelter had been constructed behind the Club House. The top of the helter-skelter was in a direct line with the laser radiation should the beam either miss the mirrors on the Club House or if the beam was larger than the mirror. The proprietor agreed that this attraction and an octopus which raised riders into the path of the beam would be closed down during each of the performances.

The lasers were mounted on piles. No account had been taken of the possibility of the piles moving as the tide went in and out. Therefore, the lasers had been aligned with the mirrors, and blanking plates fitted, with a particular tide state. This problem was identified approximately 1 hour prior to the timetabled start of the show.

The operator was not familiar with the control console. He had used similar versions but, because the console operation was heavily dependent on the version of software it was running, he had to familiarise himself with it. The major problem was that all of the effects had been programmed in during the night and supposedly saved to a floppy disk. The data had not actually been saved. This was discovered about one hour before the start of the show.

It was decided to proceed with the operator driving the show live. The lasers were re-blanked to limit the beam to at least 3 m above the height of the footpath. The Environmental Health Officer maintained radio contact with the operator throughout the show. Due to the time delay, the show started about an hour late, only three performances took place.

It was difficult to judge how many people turned up to the event. Two thousand had been expected. However, it was considered that the proprietor put a number of people off by commenting adversely about the Environmental Health Officer's interest in the laser safety on the local radio.

B.3.4 Conclusion

The only potential for exposure was during the setting up process. However, it is suggested that measures to restrict exposure were only taken because of the presence of the Environmental Health Officer. The failure to store the programme data put the operator under a lot of pressure.

Laser radiation exposure was an issue at the early stage of the design of this event. However, the mechanical issues, such as movement of the lasers and optical systems in relation to the rest of the venue, including mirror systems, and the failure of the computer system to store the show, generated the laser radiation safety issues closer to the performance time. The EHO was fully qualified to assess the mechanical issues but was not confident with the implications of the changed exposure situation.

B.4 Drive-In Movie and Laser Show D

B.4.1 Introduction

This display at an airfield was a bonfire-night fireworks display promoted by a local radio station. The laser display company will be referred to as Company D. The author attended to support the District Environmental Health Officer who felt he had insufficient expertise to assess laser radiation safety, although he was fully competent to assess the other hazards, such as electrical and mechanical hazards.

The operator was not able to provide measurements or calculations to support the planned exposure of the audience to the laser radiation. These calculations had to be carried out by the author using information supplied by the laser operator.

B.4.2 Details of the Laser System

The display was carried out with a single 20 W Spectra Physics argon ion laser. This was loaned to Company D by the manufacturer. The laser was mounted on a scaffolding tower adjacent to a mobile ‘drive-in movie’ projection caravan. The caravan provided a convenient mask to restrict laser radiation from being directed below horizontal (at about 3 m) in the direction of the audience.

The laser was used to project cartoon images on to a screen which, at other times, was being used as the projection screen for the drive-in movie. A mirror ball was positioned on the screen. Initially, the paperwork from the laser company indicated that the mirror ball would be 1 m in diameter with 0.015 m facets and located at the top of the screen. On the day the mirror ball was 0.76 m (30") diameter with 0.01 m facets and it was mounted at the bottom of the screen. Mirrors were attached to the support tower for the screen at a height of about 3 m and were directed into the sky.

The main concern with this display was the radiant power of the laser. The nominal ocular hazard distance was calculated as 2 km. The potential for any hazard could be minimised by directing the beams into the air. However, the beam path between the laser and the mirrors was horizontal. The mirror ball also potentially redirected the laser radiation into areas occupied by the public.

B.4.3 Problems Experienced

The changes from the original specification with the mirror ball meant that calculations had to be repeated on location. The Environmental Health Officer was prepared to insist that the mirror ball should not be used but required evidence to support this. The calculations demonstrated that the maximum permissible exposure levels would only be exceeded if the beam was not expanded and the mirror ball stopped rotating. Undertaking calculations under the time pressures inherent in live performances is not easy. The change of mirror ball was not considered significant by the operator, which demonstrated that the safety implications were not appreciated. However, it was reasonably foreseeable that equipment may fail and be replaced, so operators should be in a position to assess any way that the safety judgements are invalidated.

The laser was powered from a mobile generator which had been hired by the event organisers. The power cable was too short. The generator had to be dragged with a lorry to the correct position. This in itself was a hazardous operation but, since the operation took several hours to complete, meant that the laser company were pressed for time. The Environmental Health Officer had asked that the author should be happy with the laser safety aspects before the public were admitted to the site. This was not possible. The surrounding roads were becoming blocked with traffic and the police decided that the public had to be admitted. This demonstrates the importance of being able to judge the whole safety issue. A specialist laser safety adviser may not be in a position to make the necessary judgement. However, enforcing officers also need to be able to put the laser safety issue in perspective.

The laser operator assured the author that the laser optics were aligned and blanked off at his premises such that exposure below horizontal was not possible. However, this relied on the laser and optics being horizontal. The operator had no means of checking this. When he carried out the final alignment he removed the blanking plates anyway.

At the start of the first of two performances the laser tripped out due to a temperature problem. This was rectified within five minutes and the performance continued.

B.4.4 Conclusion

This event demonstrated that the laser company does not always do what it says it will do. The change of mirror ball was considered a minor change by them, as was the change of position. It showed a lack of understanding of the safety issues.

The influence of parameters outside the immediate control of the laser operator such as power cables not being long enough and the laser overheating add to the pressure operators are under.

Laser radiation became the main safety issue at this event, despite the other hazards. This was mainly because of the difficulty of carrying out the assessments under time pressures.

B.5 Trade Exhibition E

B.5.1 Introduction

Company E had been employed to put on a laser display as part of an advertisement on a stand at a trade exhibition at a Conference Centre. The author acted as Laser Safety Adviser to the venue and particularly gave advice to the venue manager responsible for radiation safety. The use of lasers at the venue was infrequent and the manager considered his investment in time to gain the necessary expertise was not justified. He was fully competent to assess all non-laser-radiation hazards.

B.5.2 Details of the Laser System

A 4 W Spectra Physics 168 argon ion laser was to be employed on a trade stand approximately 5 m by 5 m. The laser was to be mounted below a table with the laser radiation directed vertically up past a personal computer in a perspex tube. Access to the keyboard of the computer was possible through a cut-out in the side of the tube (figure B.6). The beam was then directed from two mirrors to beam stops at the edges of the stand. The structure of the stand was made from highly polished stainless steel.

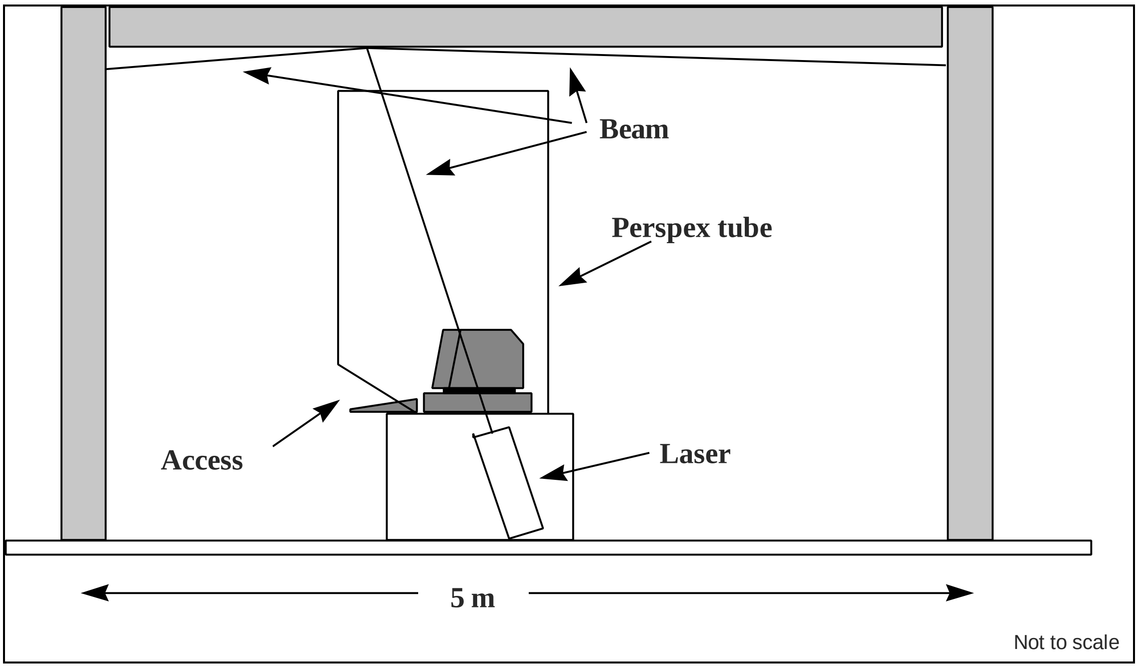

Figure B.6 Trade Exhibition

B.5.3 Problems Experienced

The diagrams of the display suggested that access to the laser radiation was relatively easy. The company were asked to justify the need to use such a high powered laser in such a small environment. They claimed it was the smallest laser they had.

A site visit during the construction of the display stand also gave cause for concern. The structure was not substantial and subject to displacement when people moved across the floor. It was therefore likely that the beam could become misaligned either with the mirrors or with the beam stops.

The author suggested to the venue manager that the laser should not be used because the safety of the visitors could not be assured. This was supported by the venue manager and the laser was not used.

B.5.4 Conclusions

The task that this laser was required to perform could be adequately achieved using a much lower powered laser, such as 20 mW. Blanking panels could have been installed to ensure that the laser radiation would not be accessible to the visitors. Consideration should have been given to the stability of the display stand.

This was an example where collaboration at an early stage could have overcome the problems. It is likely that the companies involved had put on similar displays at other venues without any questions being asked. Calculations of the times to exceed the maximum permissible exposure levels under reasonably foreseeable fault conditions should have alerted the laser company to the risk of the display they intended to put on.

The main safety issues here related to mechanical aspects of the design and construction of the display stand. The failures here made the laser radiation the main issue. The venue also took account of the potential litigation resulting from an incident or accident involving a visitor to the exhibition.

B.6 Trade Conference F

B.6.1 Introduction

Company F had been employed to provide laser effects as part of a conference for insurance sales representatives at a Conference Centre. The author acted as Laser Safety Adviser to the venue and particularly gave advice to the venue manager responsible for radiation safety.

B.6.2 Details of the Laser System

Two Spectra Physics 168 4 W argon ion lasers were used. One was installed in the projection room above the entrance doors to the theatre hall. The other laser was mounted at the rear of the stage. Both lasers were controlled by the operator located in the projection room.

The laser in the projection room was used to sign-write on a screen on the stage. The laser on the stage was initially used to produce a fan of laser radiation above the audience and to sign-write on the walls to the side and rear of the auditorium. At a predetermined point in the performance the stage laser was to produce a fan of laser radiation below the screen on the stage. A smoke generator was used to produce a fog to hide a car which would then appear through the fan of laser radiation.

B.6.3 Problems Experienced

The projection room in which the laser was installed was very cramped. Cooling water hoses came through the door which meant that the door could not be shut. The optical bench was operated with the covers removed and was positioned at about chest height. The radiation was directed through the glass screen with a gap of about 0.5 m. There were significant specular reflections around the projection room. However, measurements were not carried out to quantify the hazard from these.

The car, which was positioned behind the stage, was hidden from view during the first part of the performance by a venetian blind. This was to be operated remotely by the laser operator. The author was assured that this was interlocked such that the laser optics could not direct the radiation down until the blind had been raised. It was also pointed out that the operator could see the blind and would not activate that part of the sequence until he was sure that the blind was out of the way.

During a run-through of the display the venetian blind failed to raise but the laser operator, who later admitted that he could not see the blind with the laser on for the first part of the show, still activate the relevant part of the sequence. A fan of radiation was directed across the auditorium at about head height. The author was the only person in the direct line of the beam and fortunately he was, at that moment, watching the operator through the projection room window, ie facing the other way. The operator terminated the exposure promptly.

The car which was to pass through the laser beam had to have a driver in it to ensure that it did not go off the end of the stage into the audience. Concern was expressed to the organisers about the number of specular reflectors which could potentially direct laser radiation at either the eyes of the driver or into the audience. This was accepted and measures were taken to mask items such as the door mirrors.

B.6.4 Conclusions

This display showed that the operator had little concern for his own safety or for those who may have been in the vicinity of the projection room. It also showed that the operator had not tested the interlocks connected to the venetian blind, if they existed. The operator was visibly shocked by the potentially hazardous irradiation of the auditorium and probably learnt a good lesson.

The potential for stray reflections from items introduced into the beam had not been considered, even though some of these were actual mirrors. It was understood that no instruction concerning laser safety had been given to the driver.

The design of the event was such that laser radiation issues should not have predominated. The failure of the car to stop before it reached the edge of the stage presented a risk of death to those in the auditorium. The hazard was considered to be adequately controlled and the venue management considered that they could make the necessary judgements on the adequacy of the control measures. The main concern of the venue was that the laser radiation was something outside their area of expertise. Most importantly they considered they did not have a ‘feel’ for the magnitude of the risk associated with a given exposure situation.

B.7 Medical Laser G

B.7.1 Introduction

Entertainment is not the only time when laser radiation can potentially put the public at risk. Equipment which utilises laser radiation is often exhibited at trade exhibitions. The exhibitors like to demonstrate the equipment in operation.

Company G had been given permission to exhibit a class 4 surgical laser on a display stand at a Conference Centre subject to approval from the NRPB. The exhibitors wanted to demonstrate the cutting capabilities of the laser by giving visitors to the exhibition stand the opportunity to cut apples.

B.7.2 Details of the Laser System

The laser was a 30 W carbon dioxide surgical laser. This type of laser is generally used for gynaecological surgery. In an operating theatre it would be under the control of a surgeon or consultant trained in its use with the minimum number of support staff necessary.

B.7.3 Problems Experienced

It was difficult to see how the exhibitor could control the potential exposure of its own staff, visitors operating the laser and other visitors. Since the laser was designed to cut people, given the opportunity it would do so. The exhibitor was advised that such use was not acceptable as presented.

The Board was contacted the week before the exhibition was due to take place. The exhibitor had finished planning for the event six months previously. Early consultation may have provided a solution whereby the laser could have been demonstrated.

B.7.4 Conclusion

Laser equipment which can potentially put visitors at risk is routinely displayed at trade exhibitions. The Board's contact with the Conference Centre means that it usually can contribute to the venue's decisions on whether such equipment can be allowed to be demonstrated. However, this venue is only one of a number in London alone where such demonstrations are taking place.

Marketing staff may not have the necessary laser safety expertise. Manufacturers and distributors should ensure that consideration is given to this when products are launched or exhibited.

One of the main factors here was training. The product, in normal use, would be operated by persons who have been trained in both the medical aspects of the procedure and the safety aspects of the laser, including the laser radiation. The procedure relies heavily on administrative controls and personal protective equipment. Such control measures are not adequate when laser products are used by untrained personnel, except under extremely well controlled conditions.

B.8 Laser Games H

B.8.1 Introduction

There are a number of different laser 'tag' game systems which operate on a similar principle. Participants have a 'gun' which incorporates a visible laser and an infrared light emitting diode. The former acts as an aiming device while the latter transmits information to various targets. Each player also has a body pack which includes various target receivers.

B.8.2 Details of the Laser System

Information was provided by one of the laser game manufacturers (Megazone, 1994) and is understood to be typical of other systems in use.

The laser gun contains a laser diode emitting at 635 nm (+10 nm, -5 nm) and is part of a system using the name Phasar. The diode manufacturer's specification gives the radiated power as 3 mW (Philips, 1993). However, the specification for the manufactured gun states the following:

Table B.1 Specification for laser gun

Classification (to BS EN 60825: 1992)	Class 1
Maximum radiated power	0.95 mW
Maximum emission duration	200 ms
Maximum pulse rate	4 Hz
Divergence	3.0 mrad
Spot size at lens	6 mm x 4 mm ± 1 mm
Spot size at 5 m	contained within 15 mm diameter circle

The laser games are normally operated as a franchise. Information is supplied to the franchisee on how to operate the game safely. The instructions include a section on supervision and state that the players should "avoid pointing the Phasar into their eyes or the eyes of other players".

Other systems visited by the author, have Class 2 warning signs on the guns.

B.8.3 Problems Experienced

It is assumed that the laser radiation is coincident with the infrared radiation. Therefore, there is an incentive for the players to aim the laser at the target area of the opponents. It has been observed that some of the guns do not have the two radiations coincident. Where this has been observed, the laser radiation has always been directed higher than the light emitting diode. This error is adjusted for by skilled players. One particular system was sufficiently out of alignment that aiming at the opponent's head provided the best correction for hitting the chest pack at a distance of about 3 m.

The justification for the assignment of the product to class 1 is interesting. The relevant standard at the time was BS EN 60825: 1992 (BSI 1992). Light emitting diodes were not included within this Standard and therefore only the diode laser had to be taken into account. The accessible emission limit for class 1, as given in table 1 of the Standard, is 1.05 mW for a single 200 ms pulse. As soon as more than two pulses are emitted the product becomes class 2. The classification of these products under BS EN 60825-1: 1994 (BSI 1994), which includes light emitting diodes, is likely to result in the products being assigned to class 3B.

B.8.4 Conclusion

Most of the laser games use lasers which are class 2 under BS EN 60825: 1992 and deliberate exposure of people's eyes should be avoided. Repeated exposure may increase an individual's aversion or blink response time. A simple test jig could be supplied by the manufacturers to ensure that the laser radiation remains coincident with the infrared radiation. There are likely to be a number of other hazards associated with playing these laser games. These will include the chemicals used to produce the fog effect, the loud music and the potential for impact with the facility structure under reduced, or strobed, lighting conditions. Local authority EHOs are likely to have adequate expertise to assess these other hazards.