LASER DISTORTION
CAUSES & SOLUTIONS

Technical Guide

LS-CS-M-057

lazersafe

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Copyright Information

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1 About This Manual

This section contains information about this manual. It contains the following sections:

- Document Objectives
- Technical Competence Requirements
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- Obtaining Technical Assistance

1.1 Document Objectives

The **Lazer Safe Laser Distortion - Causes and Solutions Manual** provides comprehensive information on the causes of laser distortion, the impact this distortion has upon the operation of a guarding system, the best practices to avoid distortion in a workplace, and configuration options for operating in extreme environments where laser distortion is unavoidable.

1.2 Technical Competence Requirements

This manual has been written for the use of trained and competent personnel as defined below.

- Any engineer who is responsible for the planning, design and construction of automatic equipment using the PCSS should be of a competent nature, trained to and qualified in all relevant local and national standards required to fulfil that role. Such engineers should be fully conversant in all aspects of safety with regards to automatic equipment.
- Any commissioning or service engineer must be of a competent nature, trained to and qualified in all relevant local and national standards required to fulfil that role. Such engineers should also be trained in the use and maintenance of the completed product, including being completely familiar with all associated documentation. All maintenance should be carried out in accordance with established safety practices.
- All operators of the installed equipment should be trained to use it in a manner that complies with established safety practices. Operators should also be familiar with all documentation concerning operation of the equipment.

1.3 Prerequisites

To use the **Lazer Safe Laser Distortion - Causes and Solutions Manual**, you should be fully conversant with all critical safety aspects of laser guarding, and the press brake upon which it is installed.

1.4 Document Organisation

This manual is organised into the following chapters:

1. About This Manual.
2. Laser Guarding and Distortion.
3. Solutions for Laser Distortion.

1.5 Related Documentation

This manual (Laser Distortion - Causes and Solutions Manual) should be used in conjunction with the following documents:

- Lazer Safe Planar Laser Alignment Guide (LS-CS-M-017).
- Lazer Safe Block Laser Alignment Guide (LS-CS-M-025).

- Lazer Safe PCSS-A Series Technical Manual (LS-CS-M-046).
- Lazer Safe Folding Machine Alignment Guide (LS-CS-M-051).
- Lazer Safe IRIS Plus Technical Manual (LS-CS-M-082).
- IRIS Plus Communication Protocol (LS-CS-M-081).

1.6 Guide to Notes, Cautions and Warnings

Note:
This symbol indicates helpful information that helps you make better use of your Lazer Safe product.

Caution:
This symbol alerts you to situations that could result in equipment damage.

Warning:
This symbol indicates danger. You are in a situation that could cause bodily injury. Before you work on any equipment, be aware of the hazards involved with electrical circuitry and be familiar with standard practices for preventing accidents. To see translations of the warnings that appear in this publication, refer to the translated safety warnings that accompanied this device.

1.7 Obtaining Technical Assistance

For technical support with the PCSS-A, please email customerservice@lazersafe.com.au detailing your specific requirement.

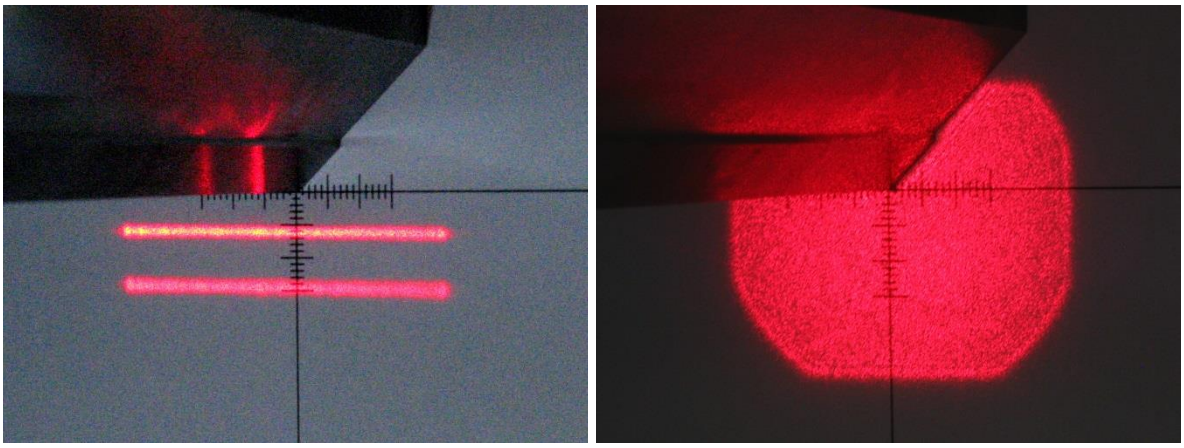
2 Laser Guarding and Distortion

2.1 Planar and Block Laser Guarding

Lazer Safe guarding systems use laser light, configured either as planar beams or ‘blocks’ of collimated light, to create a safety barrier around the danger zone of a tool. If the light beam is even partially obstructed, the safety controller will immediately take action to stop the machine.

The light is generated by a laser transmitter, which is aligned with the danger zone of the pressing tool, and emits the light in a well-defined pattern. The receiver detects the laser light using discrete sensors (in the case of a planar laser) or a camera (in the case of a block laser), and determines if the danger zone is clear of obstructions. Only when the danger zone is clear of obstructions will the safety controller allow normal operation of the machine.

Ideally the light patterns that fall upon the receiver should appear as shown in **Figure 2-1**. The planar laser transmitter (**Figure 2-1a**) emits one (single beam) or two (dual beam) parallel planes of light that are aligned at a set distance below the tool tip for the entire length of the machine (the ‘laser to punch distance’). The sensors in the receiver are divided into three regions; front, middle and rear.



(a) **(b)**

Figure 2-1: Aligned, Undistorted Planar Laser (a) and Block Laser (b) Guarding System Images.

The block laser (**Figure 2-1b**) transmits a two dimensional ‘block’ of laser light that surrounds the tool, and projects a silhouette (or shadow) of the tool onto the receiver window. A camera in the receiver captures and analyses an image of the silhouette to detect if an obstruction is present. **Figure 2-1b** shows that the transmitter has been correctly aligned to the tool, as the silhouette is a clear and accurate representation of the tool and the danger zone.

Note:
The planar and block laser images presented here were captured on a 3.4m long press brake with full tooling; the receiver target is marked in millimetres.

2.2 The Cause of Laser Distortion

Light travelling from the transmitter to the receiver passes through the air surrounding the press beam tool. The speed of this light varies depending upon the density of the air, which in turn depends upon the temperature of the air. When the light is moving through a region of constant density, its speed and direction are constant, and there is no distortion.

However, if the light passes from a region of warm, thin air to a region of cooler, denser air its velocity is reduced. This may cause the light path to ‘bend’ as it passes from one region to another, a process known as refraction.

Figure 2-2 shows diagrammatically what occurs when the light passes through regions of different density.

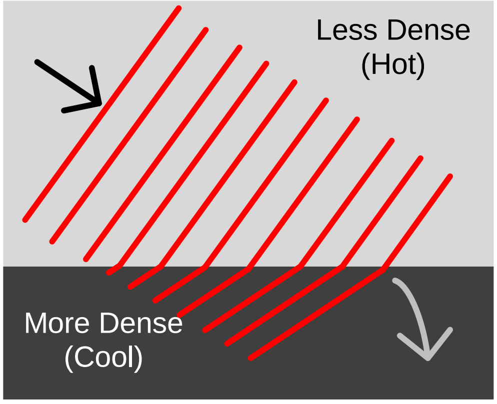
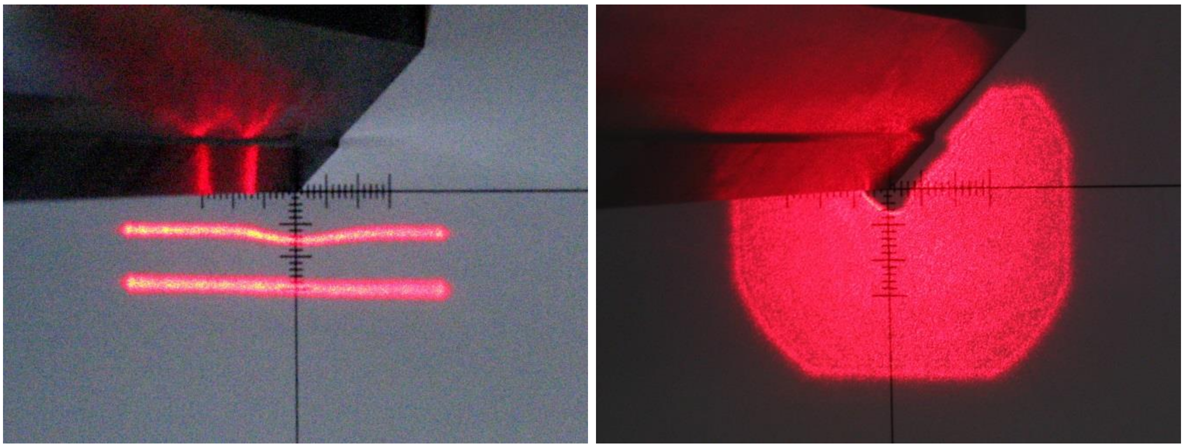


Figure 2-2: Light Refraction in Air Causing a Change in Direction

Different regions of air density can result from localised heating around the tool, heat generated by the press brake itself, and artificial heating/cooling in the workplace. The degree of distortion varies with the temperature difference, and the length of the path that the light must travel (i.e. the length of the machine).

The amount of distortion may change during the stroke, as the press beam and the laser guards move up and down through regions of differing air temperature and density. Also, depending upon the location of the machine, it may vary depending upon the time of day, or even the time of year.



(a) **(b)**

Figure 2-3: Aligned, Distorted Planar Laser (a) and Block Laser (b).

The effects of distortion can be seen in Figure 2-3. In Figure 2-3a the upper laser (Laser ‘A’) is clearly curved below the tool tip. This is caused by the punch being several degrees warmer than the surrounding air. As shown in Figure 2-2, the light is bent away from the warm tool tip by 2-3 millimetres, effectively increasing the laser to punch distance.

Figure 2-3b shows how a block laser guard is distorted by the tool being raised 4ºC warmer than the surrounding air; the mechanism of this distortion is explained in Figure 2-4. As the light travels from the transmitter to the receiver it is progressively refracted away from the tool, resulting in what appears to be a region of shadow approximately 2-3 millimetres wide around the tool silhouette on the receiver window. This shadow has thin, bright edges due to the light being concentrated at the edge of the refracted region.

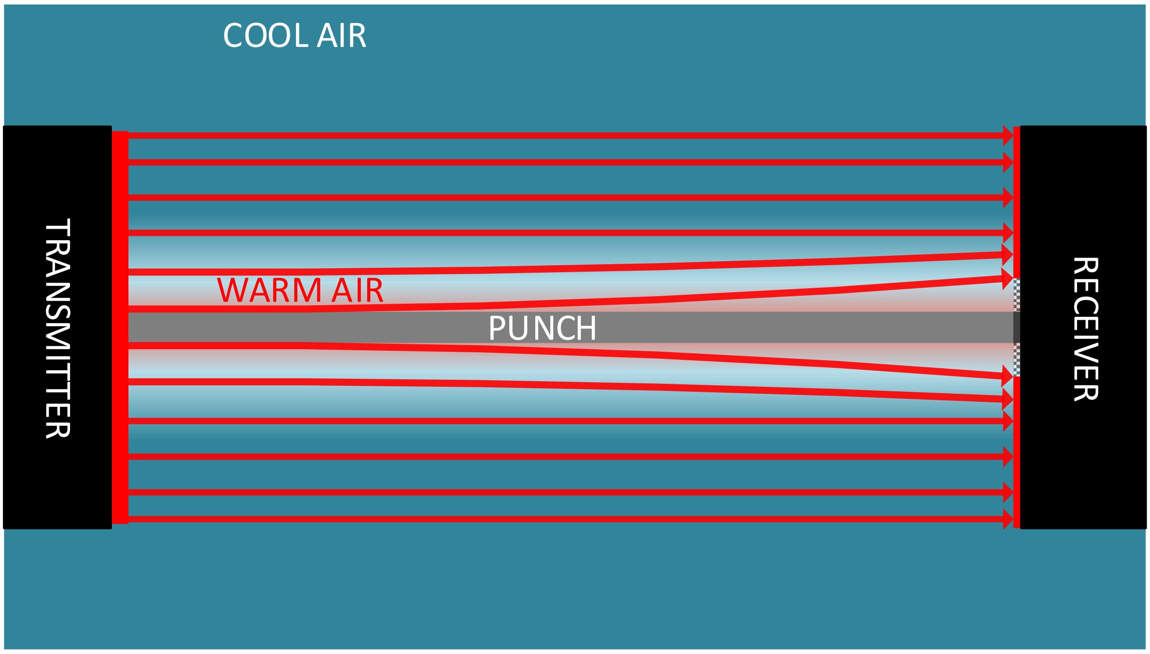


Figure 2-4: Refraction of a Block Laser (Seen From Above).

As can be seen in **Figure 2-4**, the longer the path that the laser travels through regions of different temperature, the worse the distortion. As the temperature difference is caused by heat stored in and around the tool, large machines with full tooling present the worst case for distortion effects.

2.3 How Distortion Affects Guarding Systems

Note:
In most cases distortion due to air effects has no impact upon the operation or productivity of Lazer Safe guarding systems. Robust software algorithms in the PCSS-A controller (and for block lasers, in the receivers) are designed to operate reliably over a wide range of environmental conditions, and will effectively differentiate between distortion effects and actual obstructions.

It is only under extreme conditions that distortion will have any effect upon the operation of Lazer Safe guarding systems. **Section 3** presents solutions for operating in these conditions.

Under no circumstances will laser distortion in any way reduce the level of safety and confidence provided by a Lazer Safe guarding system.

2.3.1 Planar Laser Guarding Systems

If the distortion is in the order of +/- 2mm the distortion should have no impact on the operation of the guarding system, and laser guarding will operate normally.

If the laser distortion is severe, the distorted segment of the beam can become misaligned with the receiver sensor. If this occurs as the tools are closing it will be interpreted as an obstruction, and the safety controller will halt the press beam. If the distortion/misalignment continues, the machine will only be allowed to move down in slow speed, with the guarding muted.

2.3.2 Block Laser Guarding Systems

The operation of block laser guarding systems will also be affected if the distortion changes as the tools are closing. Again, this may be interpreted as an obstruction, and the safety controller will halt the press beam. If the distortion continues, the machine will only be allowed to move down in slow speed, with the guarding muted.

In all models of Lazer Safe's block laser guarding systems, software in the receiver processes the image of the tool shadow and detects the location of the tool tip. Under normal circumstances this provides the best possible alignment for maximum safety and productivity.

It can be seen from **Figure 2-5** (and **Figure 2-3**) that the true size of the punch (left) is enlarged by the distortion (right), and the image seen by the receiver camera does not accurately define the tool tip position.

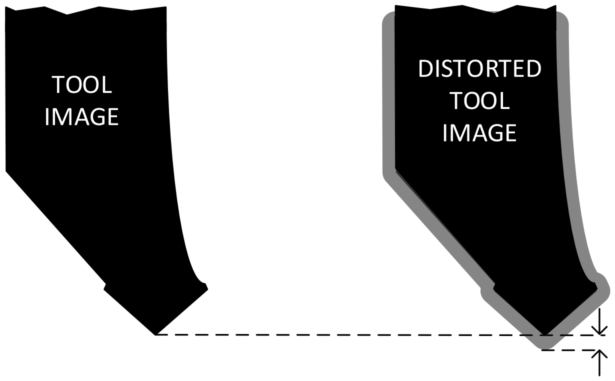


Figure 2-5: Tool Image Distortion.

In extreme cases, distortion that is constantly changing due to airflow across the tool may also make it difficult (or impossible) for the receiver to complete the tool alignment process that is required before the system can operate.

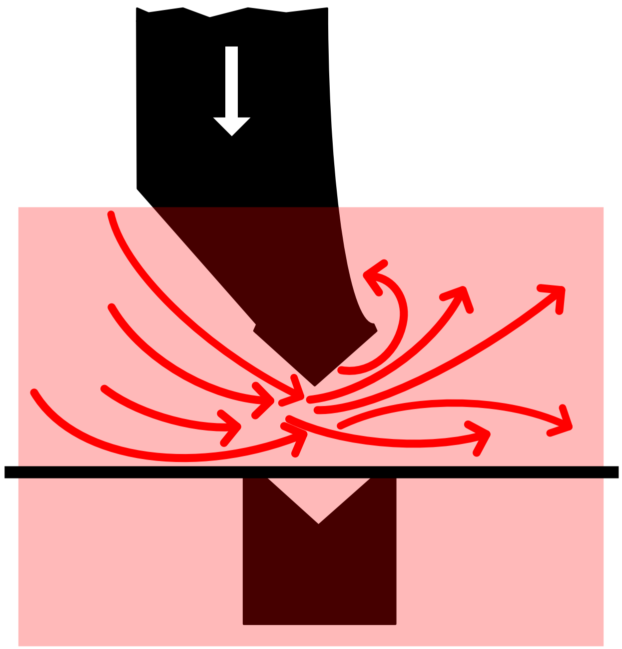


Figure 2-6: Block Laser Distortion Caused By Air Flow as Tools Close

A difference in temperature between the inside and the outside of the press brake will cause airflow between the tools. Near the pinch point this airflow is concentrated and increases in speed and turbulence as the opening between the tools closes. This may lead to localised, fluid distortion around the tool tip, as shown in **Figure 2-6**.

These changing light patterns can result in intermittent obstructions that occur close to the mute-point. Advanced Lazer Safe products that perform angle measurement may also be affected by this form of distortion.

3 Solutions for Laser Distortion

3.1 Avoiding Distortion

As described in **Section 2.2**, laser distortion is caused by differences in air temperature around the tool and the laser guard. Some precautions can be taken when installing a machine to minimise the causes of laser distortion.

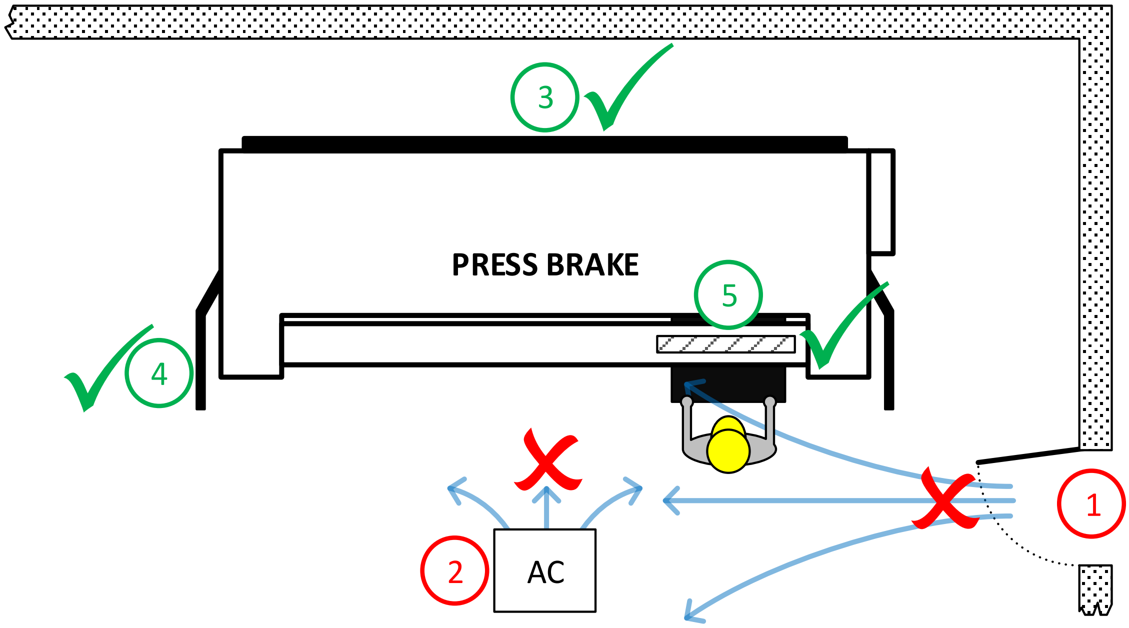


Figure 3-1: Press Brake Location and the Causes of Laser Distortion

Referring to **Figure 3-1**:

1. **If possible, avoid locations near doors or windows**. A press brake located near open doors or windows will be subjected to large changes in airflow and air temperature throughout the day. This will result in increased airflow over closing tools near the pinch point, which may lead to intermittent obstructions that occur at different times during the day.
2. **Avoid placing machinery directly under air conditioning outlets**. Ceiling or wall mounted air conditioners blowing onto the machine (either heating or cooling), can result in a large differences in air temperature close to the tools. Fan blowers can also increase the airflow over the tools as they near the pinch point.
3. **Solid back gates help prevent airflow through the machine.** Solid back gates with minimal ventilation restrict the airflow through the machine which will help to minimise the distortion caused by air flowing over the tools. Well ventilated or mesh back gates allow high levels of airflow through the machine and over the tools as they close (see **Figure 2-6**) which can lead to laser distortion and intermittent obstructions near the mute-point.
4. **Solid side gates reduce the airflow across the machine.** Solid side gates with minimal ventilation restrict the airflow over the tools from the sides of machine. Glass or Perspex gates restrict access and prevent airflow, while still allowing inspection of the work piece.
5. **Use the minimum tooling needed for a job.** The amount of distortion caused by temperature differences increases with the length of the tool. Shorter tools result in less distortion.

3.2 Operating With Laser Distortion

Steps can be taken to prevent laser distortion affecting the operation or productivity of a press brake.

3.2.1 Planar Lasers - Laser to Punch Distance

The laser to punch distance for planar lasers can be as small as 4mm. If distortion is occurring close to the tool, the best solution is to increase the laser to punch distance. Adding 1-2mm to the laser to punch distance has been shown to be the most reliable way of preventing laser distortion from causing false obstructions.

Warning:
For any planar laser guarding system the maximum allowable laser to punch distance is 14mm, as defined in ***Safety Of Machine Tools – Hydraulic Press Brakes, EN12622.***

As well as physically moving the laser guards away from the tool tip, the configuration of the safety controller will have to be changed to ensure that speed and distance tests performed by the controller are adjusted accordingly. The laser to punch distance is set in the PCSS-A safety controller ISaGRAF application; refer to the ***Kernel Interface Analogue Output #1*** section of the ***Lazer Safe PCSS-A Series Technical Manual (LS-CS-M-046)*** for details.

Contact Lazer Safe Customer Support if you require assistance or further information on how to configure your press brake guarding system (customerservice@lazersafe.com.au).

3.2.2 Block Lasers – Alternative Guarding Detection

During normal operation a block laser receiver guards a region around the tool tip as shown in **Figure 3-2**. The camera pixel resolution is 2x2mm. If an object larger than 2x2mm is detected in the guarding region it is considered an obstruction, and the press is halted.

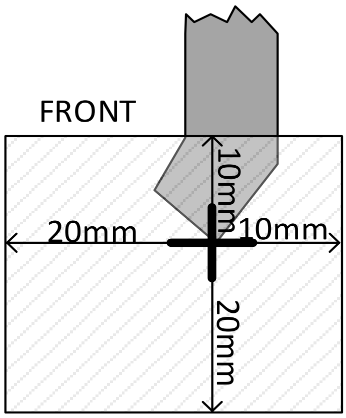


Figure 3-2: Block Laser Tool Tip Guarding Region

An alternative guarding option is provided by Lazer Safe for cases where laser distortion (or other extreme environmental factors) is present. The main features of this alternate guarding mode are:

- The algorithms used by the block laser receiver to determine the tool tip location and to detect obstructions, are modified to improve tolerance to distortion, and to other environmental conditions.
- The mute-point is raised from a minimum of 2mm, to 4mm above the pinch point.

Alternative guarding detection is one of the Guard/Counter Options of the PCSS-A safety controller; refer to the ***Guard/Counter Operation Option*** section of ***Lazer Safe PCSS-A Series Technical Manual (LS-CS-M-046)*** for details.

If you require assistance in configuring this option, please contact Lazer Safe Customer Support (customerservice@lazersafe.com.au).

4 Angle Measurement and Distortion

The previous sections of this document are primarily concerned with laser distortion around the tool tip, and the effect of any distortion on the operation of laser guarding during high speed closing.

As well as providing optical protection, the IRIS Plus system also performs advanced image processing and analysis, which extracts the angle of the workpiece as it is being bent in real time. This information can then be used as part of the bending control process to control the depth of pressing, determine the spring back of the workpiece or provide the operator with confirmation of the final bend angle.

This section describes the effects of laser distortion on the angle measurement stage of the IRIS Plus as the tools close on the workpiece, and how the IRIS Plus deals with distortion.

4.1 Laser Distortion During Pressing

Laser distortion during the angle measurement stage has the same causes described in **Section 2**; changes in air density caused by localised heating of the air between the laser transmitter and receiver.

While the main source of localised heating during guarding is the punch, during pressing the die and workpiece also contribute to localised differences in air temperature.

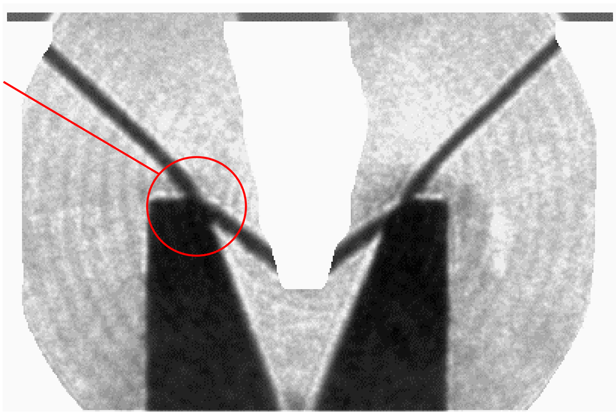


Figure 4-1: IRIS Plus Diagnostic Image of Laser Distortion

Figure 4-1 shows an extreme example of laser distortion occurring during pressing, captured in an IRIS Plus diagnostic image. Note that the image is most distorted at the points where the workpiece meets the shoulders of the die.

4.2 Angle Measurement Process and Controls

This section describes how the IRIS Plus performs angle measurement, and how this process is designed to account for non-ideal conditions.

Note:
The IRIS Plus angle measurement system is a Lazer Safe proprietary algorithm and only a general overview of the process is presented here to give an understanding of how the IRIS Plus deals with distortion.

Refer to ***Lazer Safe IRIS Plus Optical Imaging System Technical Manual (LS-CS-M -082)*** for more information on the operation of the IRIS Plus.

The IRIS Plus starts processing images at 1mm above the point where the tool tip closes with the workpiece. An image is captured approximately every 10ms in real time mode.

The IRIS Plus scans each image capture looking for the contrast between the workpiece and the reference image to find the edges of the workpiece. Data points are collected into data sets, and then analysed to determine the angle between the front and rear limbs of the workpiece.

The IRIS Plus has several control parameters that can be used to adjust data collection in the critical areas around the tool and die.

4.2.1 Exclusion Zone Controls

As stated in previous sections, the main regions of laser distortion occur around the punch and the die, as these are localised heat sources. Data points in these regions of localised distortion are excluded from the angle calculation by the Bloom setting.

Figure 4-2 shows how the Bloom value (in pixels) is added to the profile of the punch captured by the reference image to create an exclusion zone around the punch. The die information sent to the IRIS Plus in the Bend Parameters message is also used to create another exclusion zone around the die.

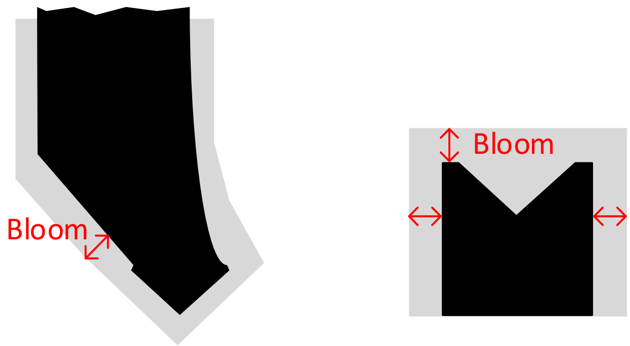


Figure 4-2: Bloom Setting and Exclusion Zone

The Bloom value is normally calculated automatically by the IRIS Plus, however it can be increased manually if required, either through the Exclusion Zone Size menu in the Configuration webpage (see **Figure 4-3**), or by the CNC sending the Set Limb and Exclusion Zone message.

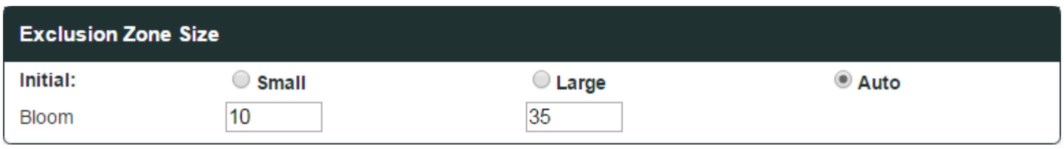


Figure 4-3: Exclusion Zone Menu

Figure 4-4 shows the same image capture as **Figure 4-1**, but with the Exclusion Zones superimposed around the punch and die. This shows that most of the laser distortion around the shoulder of the die has been excluded from the angle calculation.

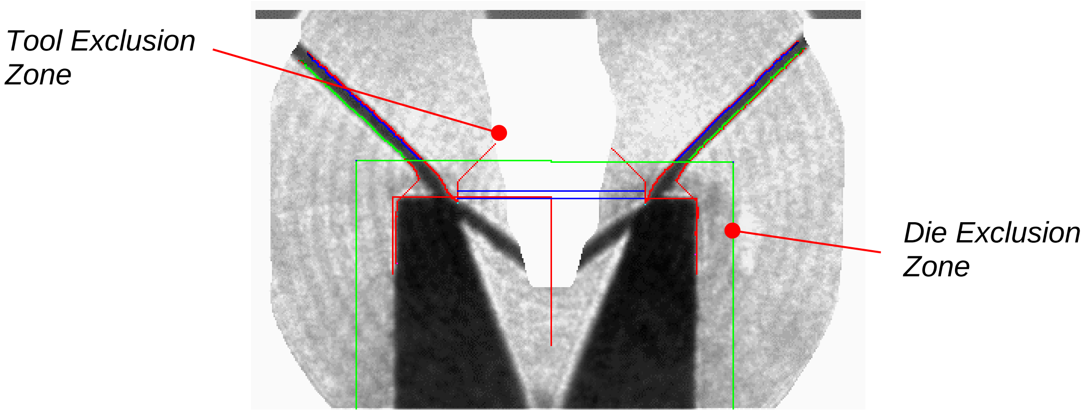


Figure 4-4: IRIS Plus Diagnostic Image of Laser Distortion With Exclusion Zone

4.2.2 Limb Measurement Controls

Outside of the exclusion zones, data points on the inside and outside edges of the workpiece are detected and collected together into limb segments. The collected data points are superimposed over the captured image in the AM_LG_THR128_XXXXX.bmp diagnostic images (these can be viewed in the Diagnostics page of the IRIS Plus webpage).

The start and end points of each limb segment (expressed as a percentage of the total segment length) are normally calculated automatically by the IRIS Plus, however they can be adjusted manually if required, either through the Limb Measurement menu in the Web Configuration page (see **Figure 4-5**), or by the CNC sending the Set Limb and Exclusion Zone message in the IRIS Plus Communications Protocol.

Figure 4-5: Limb Measurement Menu

4.2.3 Excluded Data

Aside from the data points that lie inside the tool and die exclusion zones, other data points may still be marked as invalid, and excluded from the angle calculations. Laser distortion may cause some data points to be excluded for the following reasons.

- The data point is an outlier, and is determined to be too far outside of line of the other collected data points to be considered valid.
- The data point lies on a curve.

4.3 Angle Measurement Best Practices

The effects of laser distortion on the IRIS Plus can be minimised by observing the following.

- Minimise the occurrence of laser distortion by following the guide in **Section 3.1**.
- Observe the recommended maximum machine length limits for the IRIS Plus.
- Observe the recommended maximum reference image time for the IRIS Plus.
- Always use minimal tooling, and work close to the receiver.
- Ensure that the IRIS Pus Communications Protocol Bend Parameters message is correct for each bend.
- If necessary, increase the Bloom and Segment Start parameters to move data collection away from the punch and die.
- Monitor the measurement quality figures for the bend, and alert the operator if the figure falls below acceptable limits.