ELECTRONIC FUSION WELDING

New Techniques for Jewellers

A 2013 International Specialised Skills Institute Fellowship.

DESMA NOBLE

Sponsored by the Department of Education and Training (Victoria), Higher Education and Skills Group

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i. Executive Summary

The recent introduction of electronic fusion welding for jewellery fabrication and repairs enables a relatively instant, clean join with precise control and microscopic accuracy.

“Developments in welding technology are giving jewellers an alternative to soldering that can ultimately free them to indulge in more creative pursuits.”

The superior control and accuracy of fusion welding can bring incredible productivity gains to a jewellery workshop in the following ways:

» Very fine and delicate jewellery is more easily repaired

» Metal joins can be within a millimetre of heat sensitive gems

» Less oxidisation means very little damage to the metal finish.

» Achieving joins to non-traditional metals that cannot be joined with traditional soldering

» Hand held positioning allows for delicate or complicated joins to be temporarily “tacked” in place before advanced joining.

Jewellery workshops in Australia are mostly using traditional methods of soldering and only just beginning to embrace new welding techniques, while in Europe, fusion welders have been popular for 25 years. To research and learn the skills for using this equipment, Noble headed to Germany, the country leading the way for developing and using new technology for jewellery fabrication.

The aim of this Fellowship was firstly to identify and learn the skills of using welding equipment but also to understand the specific practical applications where use of the equipment is most beneficial. The third challenge was to analyse and compare the different types of welders so that local businesses can choose and invest wisely.

Noble now uses a laser welder daily for both fabrication and repairing in her own Jewellery Studio and finds it has brought new opportunities and greater productivity to her workload. She is confident they can do the same for other workshops, large or small.

Noble has shared the techniques with her teaching colleagues at Melbourne Polytechnic and in mid-2016 presented two information to demonstrate and share the techniques and benefits with as many jewellers as possible. These will be supported and promoted through the peak professional associations within the jewellery industry. The research will also be shared in jewellery publications.

The Fellow is confident that the local jewellery industry is eager for more information and guidance on this technology are ready to embrace it in an informed and considered way.

ii. Abbreviations & Definitions

Abbreviations

GAA	Gemmological Association of Australia
GSGA	Gold and Silversmith's Guild of Australia
JAA	Jewellers Association of Australia
TAFE	Technical and Further Education
RTO	Registered Training Organisation

Definitions

Solder

(n) Metal alloys of a lower melting point applied to the joint between metal objects to fuse and unite them without heating the objects to the melting point.

(v) To unite two metal pieces using the alloy of a lower melting temperature.

Weld

To join together metal parts by heating the surfaces to the point of melting with an electric arc, laser, or other energy source. Eg: "steel plates were being welded together"

Fuse

Join or blend by melting to form a single entity.

Fusion

The process or result of joining two or more things together to form a single entity.

Electronic fusion welder

The general term for all of the welders designed to join metals together with a minute shot of energy.

Laser welding

Is a welding technique used to join multiple pieces of metal through the use of a laser beam. The beam provides a concentrated heat source enabling narrow, deep welds.

Pulse arc welding

An electric energy pulse of argon gas produces a rapid-fire zap that fuses and joins the metal.

Laser welder

Creates a weld by a laser beam which is narrowed, focused and shot in individual pulses, instigated by a foot pedal. The work is carried out in an enclosed chamber, control of energy through a digital interface and targeting of welds through a microscope.

Pulse arc welder

Creates a weld by forming an arc between a tungsten electrode and the metal in the jewellery item, in an atmosphere of argon gas to prevent oxidization. The pulse of energy is released by manually making contact under microscope and fuses the metal at the exact point of contact.

Oxidization

Any chemical reaction in which a material gives up electrons, as when the material combines with oxygen. Burning is an example of rapid oxidation; rusting is an example of slow oxidation. Usually results in discoloration.

Tack

In the context of joining metals, tack is a temporary placement, usually weakly joined together.

Binding wire

An extremely soft steel wire used to wrap around small metal parts in the fabrication process of making jewellery.

Filligree

Style of jewellery made of very fine wire detail.

Electrode

A conductor through which electricity leaves an object, substance or region.

Pickle

The process of soaking objects in a dilute acid solution to remove oxides and glassy flux residue caused by heating and soldering.

Inert atmosphere

A gas that is oxygen free and therefore non-reactive or non-oxidising. This environment assists the prevention of oxidization when metalworking.

Retipping

A repair to gem-set jewellery where the setting edge, usually claws, has new metal added to it to repair what has been worn away with daily wear.

1. About the Fellow

Name: Desma Noble

Qualifications:

» Certificate III in Jewellery Making and Repairing

» Diploma of Gemmology

» Diploma of Diamond Technology

» Certificate IV in Training and Assessment

» Jewellery Valuer 201

» Fellow #44 of The Gold and Silversmiths Guild of Australia

Occupation:

» Jeweller and Director - Desma Designs Jewellery

» Sessional Teacher at Melbourne Polytechnic, Department of Visual Arts, Certificate 2, Certificate 3 and Advance Diploma courses since 2005

Voluntary Industry Roles:

» National Councillor Gold and Silversmith's Guild of Australia (since 2010)

» Currently 'Keeper of the Punches' and Workshop Manager, Education Advisor

» Past Councillor of the Gemmological Association of Australia, Victorian Division

» Past Finalist and National Judge Jewellery section World Skills, Australia

Discovering very early her gift for making beautiful things, Noble completed a traditional jewellery apprenticeship over thirty years ago. She now has her own studio 'Desma Designs' where she designs and handcrafts bespoke jewellery commissions, as well as restoration, repair and valuation services. She is a guest lecturer at Melbourne Polytechnic for the Advanced Diploma of Jewellery Making, and the Certificate 2 and Certificate 3 courses.

Noble is a Gemmologist, Diamond Technologist and Jewellery Valuer. She currently holds a voluntary roles as 'Keeper of the Punches' on National Council of The Gold and Silversmith's Guild of Australia and is a past Councillor of the Victorian Branch of the Gemmological Association of Australia.

Noble has always been passionate about her craft and found that sharing skills and ideas through teaching is a great way to constantly fuel that passion. Desma has become a passionate advocate for the maintenance of training pathways for young jewellers, including apprenticeships. This has come about as jewellery businesses decrease apprenticeship numbers due to the high costs of training them.

2. Aims of the Fellowship Program

The key aims of this Fellowship Program was to:

» To research and personally develop the practical skills of electronic fusion welding and how these skills apply to the manufacture of jewellery.

» Learn how fusion welding techniques can improve the current practices for the repair and restoration of jewellery in Victorian workshops.

» To understand how welding techniques can be used to join non-traditional jewellery metals, like titanium and niobium, which is not possible with traditional joining techniques.

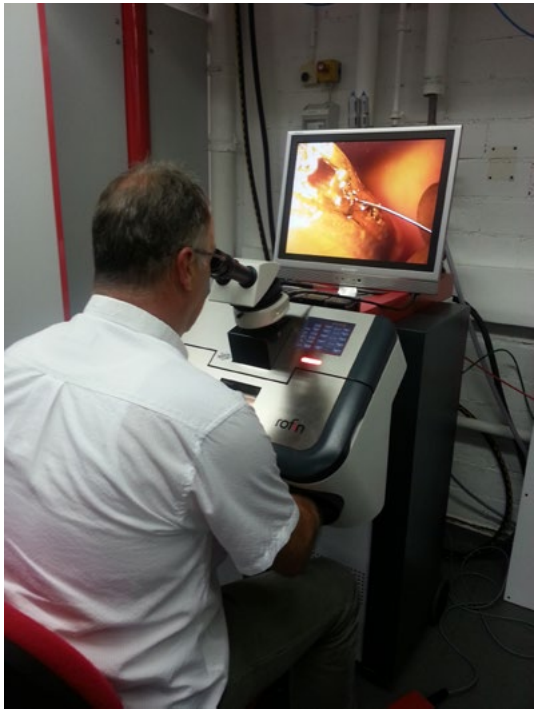
» To learn techniques of fusion welding on jewellery that contain heat sensitive gemstones. Traditional soldering techniques rely on raising the temperature to near the metal's melting point which is often destructive to gemstones. Welding techniques generate much less heat on the jewellery, allowing joins close to gemstones.

Image 1a: An Orion Pulse-arc welder being used by Wendy Jo New (photo courtesy http://metalwerx.com).

» Compare the similarities and differences between the laser type and pulse-arc types of fusion welders. Jewellers who are considering embracing this new technology need to choose between these two types, with limited access for practical trials but a sizable difference in capital outlay.

» To raise awareness of the benefits of fusion welding within the jewellery industry, and address the lack of training options for welding techniques for Victorian jewellers.

Image 1b: A Laser welder in operation by Ralf Sonnet at Rofin Baasel (Munich).



3. The Australian Context

In many Australian jewellery workshops, metal joining techniques and equipment have changed very little for hundreds of years. Jewellery fabrication techniques traditionally rely on creating metal joins by soldering with an exposed flame from a small propane and oxygen torch.

The jeweller carefully applies a ‘flux’ paste to reduce oxidization, then a small amount of solder, then introduces the exposed diffuse flame to gradually heat the highly conductive precious metal until the solder melts just moments before the surrounding parent metal does.

The following photograph shows the traditional techniques of soldering to create joins on jewellery.

Image 2: Soldering jewellery with a micro torch (photo courtesy of Mel Van Kuyk).

Image 3: Desma Noble soldering a wedding ring.

As well as requiring steady hands, there is sometimes a preliminary “set-up” process which may include using tweezers, clamps or binding wire to keep the pieces in the correct position for joining. As the solder melts and flows through the metals being joined, the challenge is to control the direction of that flow, particularly in delicate or complicated designs.

Joins created by welders are completely different, being a localised spot fusion without the more general heating or capillary effect of soldering. While welding does not replace soldering completely, many tasks can be performed more efficiently or become suddenly possible.

The following describes some of the specific benefits of electronic fusion welding techniques:

» The join is a fuse, rather than a solder. As solder is an applied metal of different alloy, there is often a visible line at the join after polishing. This can be less of a problem using a welder.

» Very little oxidation occurs with welding, saving costly hours of work to prevent or remove the discoloration, and resulting in higher quality finishes. This is especially useful in the case of antiques or laboriously applied textured finishes or electroplated finishes.

» The heat generated is so localised that gemstones that would be destroyed by soldering, can be safe while welding.

» Non-traditional, non-precious metals like titanium, steel, niobium and tungsten can be joined together without resorting to "cold-joining" techniques like riveting or screwing.

» Platinum has an extremely high melting temperature which requires greater skill and time to solder. It also means that gem set items cannot be repaired or altered without removal of the gemstones for soldering to occur. Fusion welders make these alterations and repairs both possible and incredibly efficient.

Image 4: A ring being laser welded (photo courtesy of Rofin).

Image 5: A ring being welded with a pulse arc welder (photo courtesy of Orion Sunstone Welders).

Martinez noted that "Either method (of welding) is a vast improvement over soldering. One can connect metals with no fear of firescale, or more importantly, causing damage to precious stones that already are in place."[1]

"Since the early 1980's when import tariffs were drastically reduced, Australian jewellers have struggled to compete with mass produced jewellery from overseas. With higher labour costs and the smaller local market, most retailers now source their stock from off-shore manufacturers. Australian consumers seem almost indifferent to the origin or ethics of their purchases, and consistently choose to bargain hunt at the cost of quality.

1 Martinez., Y (for Metalwerx), 2014, 'Pulse arc welders for jewellers, the revolution is now!', <www.ganoksin.com> accessed 5 February 2016.

The result is that the jewellery workshops that are operating and viable are predominantly doing repair work, or are those who positioned themselves at the higher end, doing commissions of small volume bespoke jewellery where the design and personal service element provide a marketable point of difference. In this tough economic environment, jewellery workshops need any efficiency or productivity gain that becomes available through new technology, to remain competitive. Sales of fusion welders have been booming in the United States and Europe for many years."[2]

Australian jewellers however, have been slower to invest in the technology. This is probably explained by these factors:

» The considerable capital outlay. Welders are priced between approximately $8000 and $50,000 AUD

» The limited exposure to the benefits of the equipment. With small businesses spread across the huge Australian countryside, and distances to attend trade fairs or industry gatherings, being so large, this is not surprising. The jewellery industry does have a reputation for being notoriously disconnected, and fractured.

The limited exposure to training in the techniques of fusion welding. There are stories of local workshops buying these machines only to sell them six months later because they could not put them to enough use.

For jewellers to fully embrace the benefits of the welding technology they need to access practical training locally. Melbourne Polytechnic is the main Registered Training Organisation (RTO) in Victoria offering nationally accredited vocational jewellery courses. The 2014 Melbourne Polytechnic enrolment numbers were:

» 10 students in Certificate 2 (pre-apprenticeship)

» 30 students in Certificate 3 (mostly indentured apprentices)

» 40 students in Diploma course

» 100 students in Advanced Diploma.[3]

With no RTOs offering fulltime vocational jewellery training in Tasmania, Queensland or the Northern Territory, the Melbourne Polytechnic gains enrolments from across Australia. The Melbourne Polytechnic currently has no welders of any type, so up-to date techniques for joining metals are absent from the curriculum. Adopting the fusion welding technologies is essential for the vocational training to stay current with the needs of industry.

Image 6: Rofin laser welder in use (photo courtesy of Rofin).

2 Yleana Martinez (for Metalwerx), 2014, 'Pulse arc welders for jewellers, the revolution is now!', <www.ganoksin.com> accessed 5 February 2016.

3 Guiney, C., Coordinator Jewellery Section, Visual Arts Department, Melbourne Polytechnic, 26 March 2016.

Image 7: An Orion welder in use (photo courtesy of Sunstone Products).

When the technology and techniques of fusion welding become more widespread in Australia, jewellery workshops can be more productive and efficient for both fabrication and repair processes. New possibilities will arise for innovation in design as well as jewellers experiment with joining materials where it was not previously possible. A local product that is higher quality, produced more efficiently, and at the cutting edge of design, is an exciting potential outcome with cultural as well as economic benefits.

4. Identifying the Knowledge and Skills Enhancement Areas

To identify the skill enhancements areas required, the Fellow focused on practical applications that make the new technology so beneficial to jewellers. The two main types of welders that have been examined are Pulse-arc welders and Laser welders.

Pulse arc welders create the weld by forming an arc between a tungsten electrode and the jewellery item, in an atmosphere of argon gas to prevent oxidization. It is a miniature TIG welder (Tungsten Inert Gas). The pulse of released energy fuses the metals that are touching at that exact point of contact.

Laser welders work by a flashlamp which produces a laser beam which is narrowed through a YAG crystal and focused by a series of lenses and reflectors. The beam is focused and shot in individual pulses, instigated by a foot pedal. The work is carried out in an enclosed chamber.

Both instruments have binocular microscopes to enable very exact location of the weld.

The skill in creating a successful weld with this technology is controlling the size and the power of the energy pulse that is used. This is crucial to ensure the weld is durable, strong and visually appropriate for the specific application.

It is crucial that the operator develops the skill in choosing the best balance of energy settings for the particular application. For example too much power could blast a hole in an irreplaceable collectable antique. Alternatively, a weak and brittle join on an engagement ring repair may result in a setting claw being too brittle and breaking off, leaving a sentimental diamond unsafe.

Image 8: A laser welder being used by Brigitte of Sirolasertec in Pfortzheim, Germany.

The energy parameters are changed on the welding machines by using a digital interface.

The setting variables include:

» Amount of energy used, or power of the pulse.

» Duration of energy used.

» Diameter of the welding spot.

» Frequency of the pulses.

These variations will be selected by the operator depending on the specific application.

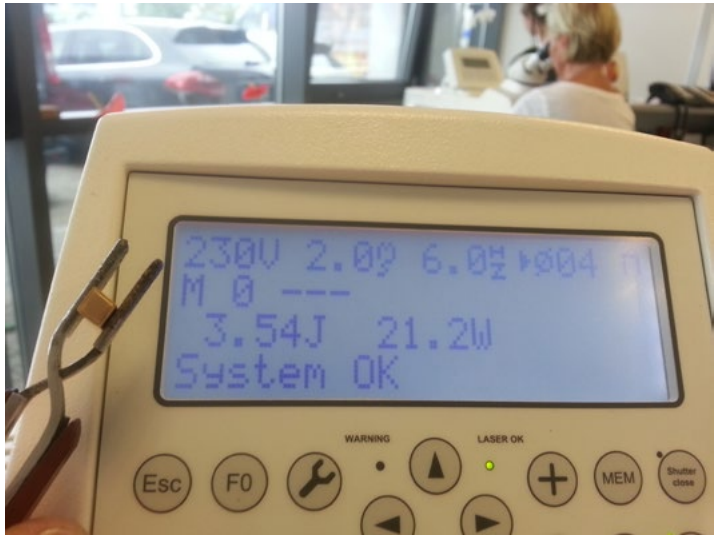


Image 9a: The digital interface of the Orion pulse-arc welder (photo courtesy of Orion Sunstone website).

Image 9b: The digital interface screen for the Siro Lasertec laser welder.

Image 9c: The digital interface screen for the Rofin laser welder.

The following are practical applications where laser and pulse arc welders are most beneficial:

» Particularly fine delicate pieces where tiny joins are required. In these joins ability to aim and pinpoint the energy and therefore heat means there is no accidental impact on the surrounding detail. Examples include fine filigree jewellery, mesh type links in bracelets and necklets, articulated sections like flexible watch bands. Soldering in these situations can be unsuccessful, as the molten solder is inclined to flow into unwanted sections. In the case of articulated watch bands for example this results in an unwanted solid section at the point of repair. The following images are some examples of this:

Image 10a: A Victorian gold and diamond locket that has been restored using welding techniques.

Image 10b: A Gold Omega articulated watch band that has had a large section replaced to restore it to functional condition. The links have maintained the ability to move and flex after repair as the join has not created a solid stiff section as it would with soldering.

» Platinum jewellery where the extremely high melting temperature of 1770 degrees means that soldering with a gas torch is very costly. It requires very high skill and is time consuming. A weld from a pulse arc or laser welder on the other hand are extremely well suited for platinum due to the very high temperature created in an extremely localised delivery. The following images are some examples of this:

Image 11a and Image 11b: A diamond set platinum ring. The ring is broken right through but soldering would heat the entire piece resulting in damaged diamonds. Image on right shows the weld completed with filler wire building up the join, ready for the finishing process. Because welding made a repair possible, a full remake of the ring has been avoided.

» Doing repairs to worn or damaged jewellery that contain gemstones. In these cases it has been the practice to skilfully remove the gemstones from the setting, then carry out the repair or alteration and then reset the gems. Sometimes, however the very process of removing the gemstones is the cause of doing even more damage to condition of the piece. Fusion welding enables the placement of a metal join within half a millimetre of a gemstone. The energy being contained to such a pinpoint spot means no damage to gemstones. This is an incredible time saver to repairing practices and even means some repairs

are possible when they would not have been using soldering techniques. The following images are some examples of this:

Image 12a and Image 12b: An emerald ring Noble photographed during alteration. A sleeve of springy metal is being added to the inside of the band to make it smaller to fit the wearer. This would be impossible with soldering techniques as emeralds are extremely fragile and heat sensitive. Even removing the emerald from the setting would probably require complete destruction of the ring mount, meaning that remaking would be the traditional solution here. The simple weld behind the setting shown has provided a solution which is vastly less time consuming and costly.

Image 13: The diamond set platinum ring has just been made and the diamond set into it as the last stage of construction. However, a small crack appeared in the corner of the setting which could not be soldered without risking the diamond. The welded repair (shown with permanent marker) within a millimetre of the diamond is a successful save of the entire piece.

Image 14: The two platinum rings (joined together) were worn down, particularly at the claws, from age and wear. This requires a repair called "retipping" which is very common in jewellery workshops. The photograph shows the ring after retipping using the laser welder which would not have been possible with soldering techniques. Again, a huge productivity gain for the jeweller.

» Two pieces of metal can easily be tacked together while being hand held using a welder. The alignment and orientation can then be checked before a more permanent bond is executed. This eliminates time consuming use of binding wire or clamps clamps and jigs which is necessary when soldering techniques are used.

Here are some examples of the complicated setup process using soldering techniques:

Image 15: A ring comprising three bands being joined together using the soldering technique. Here the jeweller is using complicated arrangement with spacer metal and binding wire holding the shape while the melting temperature is achieved under the torch. (photo courtesy of Young Jewellers Facebook Group)

Image 16: An opal ring that is held together with binding wire to enable the setting to be soldered into place.

By contrast the ring to the right has been “tacked” into place by welding:

Image 17: A complicated diamond cluster ring being assembled using spot welds to “tack the pieces together”, before final joining later (work and photo courtesy of Harry Rose, jeweller).

» Welding allows non-precious metals like titanium, niobium aluminium and tungsten that are not traditionally used in jewellery to be welded together. Soldering is not viable for joining these metals. Traditionally a jeweller resorts to cold joining techniques like rivets and screws for connecting thee metals.

Image 18: Vessels by award winning Australian metalsmith Larah Nott - these are made in titanium and would not have been possible without the use of a laser welder (photo courtesy of Larah Nott).

» Different metals being combined together, such as gold and platinum, or gold and titanium is much more feasible with fusion welding techniques. Combining these metals with traditional soldering is difficult and sometimes not feasible. The extremely different melting temperatures causes problems with controlling the direction of solder flow as well as solder joins showing as an unpleasant line after finishing. Welding can diminish some of these issues.

Image 19: A necklet in titanium and 18ct yellow gold. Joining is much easier with welding the two metals.

Image 20: Gold and steel combined in a watchcase.

» A welded join can create a better finish, than a solder join would, with no visible line. This is the case because a seam created with a welder is a fusion of the existing metals rather that a line of solder between metals. There are some cases, however where a weld seam can be more brittle. This comes about because the seam is created by a line of overlapping individual pulses so experience soon teaches an operator to identify which applications are most suited to fusion welding or soldering.

» Filler metal can be used to build up an area where it is needed. This filler material is usually fine wire of the same metal as the surrounding metal, and is manually fed into the front of the weld pool. This can be to strengthen a worn away section of a piece, it can be to fill a hole. Often an initial weld will result in a depression. This is a problem ideally remedied by a second pass with the welder while feeding in the filler wire to fill the depression.

Image 21a and 21b: Gold and silver combined in rings.

»

Image 22: Filler wire being used with a laser welder (photo courtesy of Laser Star).

- For tiny localised spot welds, where there is porosity, or cracking. This may be due to a minor imperfection in a piece that has been cast or weakness in the grain of the metal. In this application, fusion welders enable the jeweller to fill the spot with a smooth finish and minimal heating, making the surrounds less affected by oxidization. While it should be noted small splashes of molten metal can be caused by this technique, it can reduce the number of drill bits consumed by the workshop.
- Some added benefits of the use of welders include blasting holes instead of drilling them (laser only). A shot of high powered energy can perforate directly through metal thickness. This is a way to improve accuracy over the technique of manual control of a flexible shaft drill that is usually used. This reduces the number of drill bits consumed.
- Secondly a high-powered shot can be used to blast out a drill bit that has broken off in the metal during fabrication. Removal otherwise, can be extremely difficult and jewellers often resort to soaking the piece in strong acid for a lengthy period to corrode the drill bit enough for removal. Faster removal means the making process is not hindered.

4.1 How to choose which welder to buy, laser welder or pulse-arc welder?

Jewellers will need to compare laser type welders to pulse-arc type welders. Both welders fuse metal with a relatively instant, highly controllable pulse that is delivered under microscopic vision. The size of the investment, however is very different with the pulse arc type welders being approximately a quarter to a third of the price of the laser type welders.

Properties that both types of welders have in common:

- Digital control interface for quick and easy setting changes, and highly accurate control.
- Pre-set parameter settings for faster set-up time or customised memory settings for convenience with multiple uses.
- More than ample power ranges for any jewellery applications
- Option for using an inert atmosphere (argon gas) for applications where oxidization needs to be reduced or eliminated. For example when welding titanium and other highly reactive metals.
- The ability to “tack” two pieces together in a temporary bond whilst being hand held, by using low range settings.

» There are very few significant safety issues with these welders. With laser welders the laser is inactive if the chamber is open. A burn may happen due to poor finger positioning, but is probably more minor than those likely to come from a micro-torch in a soldering mishap. Eyes are more protected from flying metal in the case of laser welders due to the machine creating a barrier.

» Microscope and “Cross-hair” vision for precision and accuracy, a feature on all of the fusion welders.

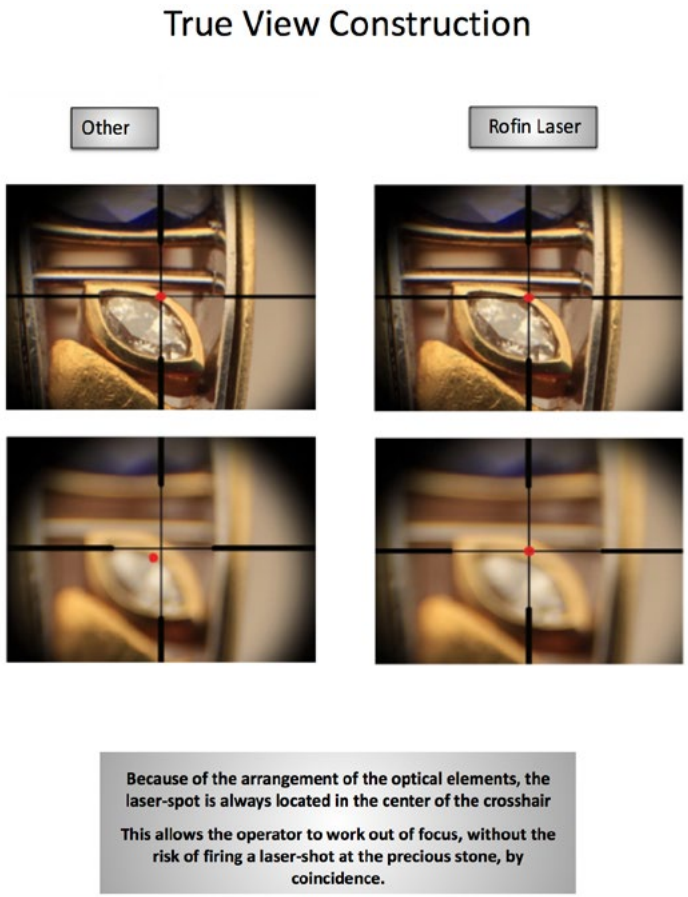


Image 23: The crosshair view through the microscope ensures accuracy of the spot weld. (image courtesy of Rofin)

Consumables for the different welders:

A Pulse arc welder consumes tungsten electrodes and the constantly running argon gas, whereas the laser welder consumables are water-filter and air-filter approximately once a year and possibly a flashlamp replacement very infrequently.

Both pulse arc and laser type welders achieve a successful weld in rapid turn around time. Once parameters are chosen the item is held at the correct orientation, and the arc or beam are activated and the shot is fairly instant.

The heat generated is extremely localised. The result is that pieces can be hand held for correct positioning for the welding process. It also means oxidisation is negligible, which is vital for items like an antique brooch with a patina to the surface that cannot be replicated if it gets discoloured during repairs.

Points of difference between the welders:

The advantages laser welders have include:

Image 24a: IWeld desktop model made by Laser Star. Image 24b: Siro Lasertec Desktop model Laser welder. Image 24c: Rofin desktop Laser welder.

» A narrower, or smaller diameter weld spot is possible, down to 0.05mm! (depending on model).

» Accessibility to hidden places is the main advantage of these welders. A narrow beam can pass through a tiny space to weld something on the other side. If you can see it through the microscope then you can weld it. For example, to weld through the inside of a filligree sphere, on the far side.

» There is a larger range of settings possible with the parameters that are selected than is possible with the pulse arc welders. This is mostly noticeable at the lower end of the parameter range when the laser will be better for lower settings for power, and pulse duration.

» The laser itself is activated by foot pedal, with no electrode, grounding clips or anything else required to make the welding process begin. A weld is as simple as: choose the parameter settings required; focus the binoculars; orientate the piece; and, shoot.

» The laser welder can achieve a much faster, or higher frequency of pulses than the pulse rate of arc welders. Depending on the brand and model, the maximum frequency will be between 25 and 50 pulses/second. Arc welders operate on about 2 pulses per second at best. This makes laser welders more suitable for longer seam welds or where there will be multiple passes with rapid firing shots. The result is a good quality weld with adequate overlap of weld spots.

» Some suppliers can arrange finance, making the purchase achievable over period.

» Local distributers are dealing in laser products exclusively, which means they have strong product knowledge and offer after sales technical support. The pulse arc welders, however, are only supplied in Australia by general tool suppliers who are not specialists in the technology. This means less likely to provide technical support and training.

» The enclosed chamber of laser welders and type of energy used means there is very little risk of ultra-violet glare causing damage to the eyes of onlookers. With the Pulse welder the exposed glare of ultra violet light means an observer needs welding glasses for protection.

» Laser technology has the advantage of not using electrodes. The negative for the pulse welders is the fairly frequent need to remove the tungsten electrode to clean up the tip using diamond impregnated wheels. The second negative about the tungsten electrode needle is that it can contaminate the weld with Tungsten as quite often the needle sticks to the welding spot.

» Argon gas can be connected to provide an inert atmosphere for welding. This helps to eliminate oxidisation and is required for the welding of metals like titanium. It is not required to be on all of the time, which is the case with pulse arc welders.

» With the pulse arc welders you cannot weld in a recessed or hidden place. Examples are inside of a cage or sphere shape, as the plasma arc is always searching the shortest connection. With the laser welder, however, if you can see it then you can weld it, which can be a significant benefit with particular applications.

The advantages of Pulse-arc welders:

Image 25: The Orion Pulse-arc welder.

» The significant advantage of the pulse arc type welders are that they are only approximately a quarter to a third of the price of the most basic laser welders.

» The feature of a large touch screen interface with easy to follow graphics is very user friendly.

» These welders have a much smaller footprint in the workshop, with individual units taking up about a quarter of the space of laser welders. This may be significant for smaller workshops where space is an issue.

» Pulse arc welders do not require a dedicated 15 ampere power outlet, whereas laser welders do.

» The exposed welding area of pulse arc welders, rather than an enclosed chamber, means quicker and easier access. Some jewellers even find it so accessible that they utilise the microscope aspect for all of their work.

Image 26: A pulse-arc welder in use (photo courtesy of http://metalwerx.com)

» As energy for the weld is from a pointed tungsten electrode, the focal point not as crucial in determining the quality of the weld as it is in a laser weld.

» To tack with these welders you can use a resistance setting so that the weld is created by metal contact rather than the arc from the electrode. This is a variation that seems, to the Fellow, neither an advantage nor disadvantage - just an operational difference.

» These welders are operated by either foot pedal or trigger setting. The trigger setting allows the pulsed arc to be instigated by contact with the electrode.

» Any by-standers watching someone use a pulse arc welder need to wear welding glasses to prevent ultra-violet glare causing eye damage.

» The pulse arc doesn't generate quite as much heat as the laser welder so, for materials like silver which is highly conductive of heat and bigger jobs requiring more repetition, the item will become too hot to hold in the fingers with the laser welder, long before this happens using pulse arc welder.

» The larger, deeper weld pool that is needed to create a deep and strong join in sterling silver is often considered to be more easily achieved with the pulse arc welders.

In 2015 correspondence with Ian Dun (Genesis Jewellery), he noted that "One negative of all fusion welders is that welds are created one individual spot at a time. While this is a huge benefit for the situations mentioned, it must be understood that there is no molten metal to flow and simultaneously fill in cracks as solder will do in traditional soldering techniques. Welders make a lot of things possible that aren't otherwise but will never replace soldering completely."[1]

1 Dun, I., (personal communication 26 October 2015).

5. The International Experience

Location 1: Rofin-Bassel Lasertech GmbH, Starnberg, Germany

Contact: Ralf Sonnet, International Sales Manager (personal tuition)

Image 27: Ralf Sonnet demonstrating laser welding techniques at the Rofin Workshops in Munich.

Outcome:

The Fellow was fortunate to be given the opportunity of personal tuition in the use of laser welding technology manufactured and supplied by Rofin-Bassel Lasertech GmbH, in Munich.

The Fellow learned:

- The history and culture of Rofin-Baasel Lasertech
- The technical development and workings of the laser machines
- Practical instruction to focus the microscope
- A detailed understanding of the variable parameter settings.
- Correct positioning of the jewellery piece in practical joining weld applications
- An in-depth understanding and practical experience on which parameter settings are best suited to which applications
- Recognition of a successful high quality weld.
- Techniques to finish and tidy the weld
- Variations on use such as blasting holes, filling holes or making spheres from fused wire.

The teaching station at Rofin has a camera fitted inside of the laser welding chamber and a screen showing the magnified work in progress. The Fellow considers this a brilliant teaching tool for this technology. This approach allows a rare microscopic insight into the delicate process underway, as it is executed by an expert.

Tours of the entire Rofin-Baasel plant included demonstrations of a variety of laser technologies, such as laser engraving and laser cutting equipment. Noble was impressed by the professionalism of the organisation and the enormous pride amongst the staff about development and capability of the equipment they produce.

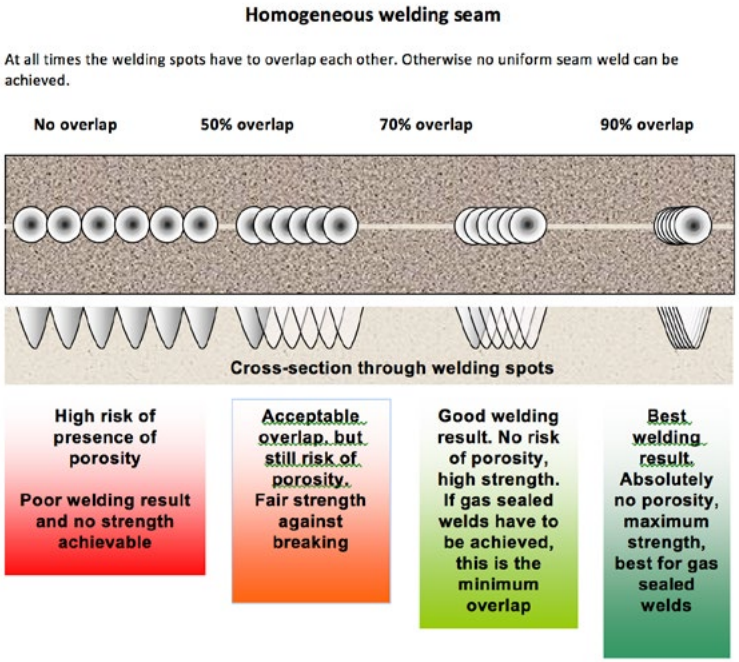
Pulse-Peak-Power in kW = the higher this value, the deeper is the penetration and the ability to weld metal, which is reflective to the laser-radiation (Copper, Silver, Fine Gold, Aluminum)

The pulse-peak-power is limited by the efficiency of the laser resonator and other factors.

Pulse-time in ms = represents the “ON-time” of the laser-lamp. The longer the pulse-time, the more metal gets liquefied. Increasing the pulse-time will extend the diameter and depth of the melting pool.

Pulse-energy in J = the higher this value, the more metal will be liquefied by a laser pulse. It is calculated by pulse-time multiplied with peak-power

Pulse-frequency in Hz = represents the ability to fire a series of pulses at a certain repetition rate



Application: Welding of sheet metal with identical thickness and alloy

Basically: the gap should be as small as possible (ca. 1/10 of the thickness of the basic material). To ensure a 'thermal contact' both parts have to touch each other. This is the only way to achieve a homogeneous welding seam.

The thinner the parts, the more difficult it is to position them correctly to each other.

The gauge or the volume of the parts rules the parameter beam-diameter, pulse-time and pulse-frequency.

The thinner the parts, the smaller the beam-diameter, the shorter the pulse-time and the lower the pulse-frequency has to be.

The alloy and/or the favoured penetration are ruling the Voltage/power. The higher the required energy (see chart above) and the deeper the penetration, the higher the voltage/power has to be set.

» Generally: the thinner the parts, the smaller the beam-diameter has to be.

» A small beam-diameter necessarily leads to a high density of energy (J/cm²). Once parts are very filigree (< 0,2mm), both voltage/power and pulse-time should be set to low values.

» If the pulse-frequency too high, the object might overheat and probably liquify.

» Once the voltage/power is too high, the laser just drills a hole.

» If pulse-time is too long, the welding spot might distort the surface and the thin object might melt.

Image 28: Recommended setting parameters of the Rofin Laser welder and the use of overlapping spot welds to create a continuous weld.

Choosing the best parameter settings for the application:

Power Selection is based on the metal alloy you are welding and the depth of penetration you require. Silver and gold require the higher power settings and platinum and steel at the lower end. The deeper the penetration desired, the higher the power level required.

Beam size (diameter in mm) factors to consider here are the metal thickness and volume of the piece. The thinner the metal to be welded or the smaller the piece, the smaller the diameter you should select.

When a smaller beam size is selected, it means the energy is condensed into a smaller area, so it has a higher density of energy. It will seem more powerful, and penetrate deeper than a pulse of the same power with a larger diameter will. So for really fine metal, like filligree work, you would select a small beam size, say 0.3mm, but it's important that the power is also on a very low setting.

There is considerable skill required in creating a continuous welding seam instead of individual spot welds. The challenge is that unless the seam is homogenous, the seam will be brittle and full of pit holes. The important rule is that the weld spots must overlap each other ideally 80-90%. See below:

Noble observed many applications of laser technology such as:

» Laser cutters and laser printing machines at work in production lines.

» Demonstration of programming several machines for production.

» Testing facility where the staff were creating extreme practical applications to test the capability of specific machines

» Displays of printing plates for producing notes of various currencies produced by laser engravers

» Displays of various items produced by laser cutter machines. Some examples were titanium surgical implant products like heart stents and limb prosthetics.

Outcome:

The Fellow left the Rofin Baasel factory with a thorough understanding of the technology of laser welders, as well as a really good foundation of the skills of using the laser welder, and the many different jewellery applications.

Location 2: Stadt Meisterschule fur das Gold and Silberschmeide handwerk

(Master School of Gold and Silversmithing), Munich, Germany

Contact: Doris Hoffman, Principal

The School for Gold and Silversmithing is a vocational school offering a three and a half (3.5) year full-time bachelor degree, which is supplemented by one year of work placement in the jewellery industry.

Frau Hoffman gave the Fellow an extensive tour of the jewellery workshops and the school's exhibition area. Frau Hoffman expanded on the curriculum and facilities on offer at the school and encouraged Noble to interview students preparing for their graduation.

Image 29a and Image 29b: Some of the equipment and workshop at the Meisterschule.

Image 30: Frau Hoffman giving the Fellow a tour of the workshops.

Being the end of the school year, the timing was perfect to mingle with the final year students who were setting up the exhibition area within the school for the opening night of their Graduate Exhibition. This was culmination of three and a half years of full time study for the bachelor degree, followed by a Masters year, which includes work placement.

The Graduate Exhibition presents the 'masterpieces' that showcase the talent of the 18 graduating students and acts as a public launching of their careers. The most prestigious achievement Award on offer is the 'Danner Prize'. This is an annual acquisitive prize funded by the Danner Foundation, an organisation which also funds the world class collection of contemporary art jewellery on display at the Danner Rotunde in Munich. In this way the Foundation are able to continually expand on the diversity of the famous jewellery collection at the Danner Rotunde.

Noble examined the exhibition masterpieces and interviewed the excited graduates about the techniques and practical development of their work, particularly regarding the use of welders. The School has been using laser welders and a pulse arc welders as everyday tools of the trade for approximately 25 years. Almost every exhibited piece would have been almost impossible to create without the use of these welders. Students took for granted the availability of the equipment and expected it to be available in their future workplaces as well.

In addition to observing the equipment used, it was interesting to compare their goldsmithing course and curriculum to those in Australia. The Munich course is longer than those offered at Melbourne Polytechnic, where Noble teaches, and the Munich workshops also had a greater variety of equipment. The Fellow was extremely proud of the standards of vocational training in jewellery making in Australia as the diversity of design and technical execution displayed in the Munich students' work was comparable to these prepared by local students.

Location 3: Danner Rotunde Jewellery , Pinakothek der Moderne, Munich, Germany.

The Pinakothek der Moderne is the 'Modern Museum' in Munich where, since 2004, contemporary jewellery has a permanent display in the Danner Rotunda as well as in temporary exhibitions. Multifaceted artistic forms of expression are permanently presented in a world class museum, sitting alongside art, architecture, graphic works and design.

The Danner Rotunda forms a central core in which exhibits by more than one hundred jewellery artists from around the world are shown – thanks to the commitment of the Danner Foundation with its extensive collection and private donors, as well as gifts from individual jewellery makers.

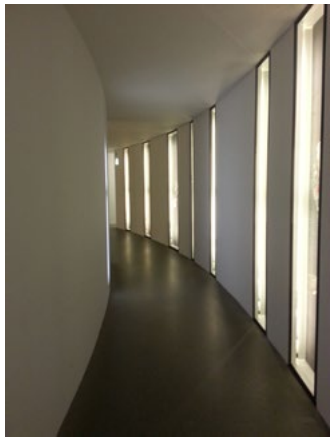


Image 31a and Image 31b: The Danner Rotunde with its inspirational architecture

The first presentation was curated by Prof. Hermann Jünger, the director of the jewellery class at the Munich Art Academy between 1972 and 1990, together with Otto Künzli who took over the professorship in 1991. Through the revamping of the Danner Rotunda in 2010, Karl Fritsch – as the representative of a younger generation – set a completely new accent.

This permanent exhibition is result of cooperation between the Danner Foundation in Munich and Die Neue Sammlung (The International Design Museum) of Munich.

The design and architecture of this permanent exhibition space, including lighting and quality of installation is inspirational. The world class collection of contemporary jewellery within is unparalleled in its diversity and depth. The Fellow came away from this experience with a dream of Australia one day having an acquisitive award like the Danner Prize and a contemporary art jewellery collection that would grow for posterity as a result.

Location 4: Siro Lasertec GmbH, Pfortzheim, Germany.

Contact: Sylvio Valenta, Director

Siro Lasertec offers high-class laser-systems, including laser welders, laser engravers and laser cutters, for industry and trade. As well as producing the laser equipment, the factory at Pfortzheim have a team of jewellers who offer practical laser-welding to industry. This team are operating their laser welders all day, every day, contracting work from all over the world.

The Fellow was provided with her own laser welder, and sat alongside the welding team, for a week to practice under supervision and to observe the other welders working on the incredibly varied applications. These are probably the most experienced users of this technology in the world, and the Fellow is incredibly grateful for the opportunity.

The welding tasks included batches of surgical parts, automotive engine parts, electronic components, as well as luxury bespoke jewellery pieces. There were also repairs of all descriptions. The Siro Lasertec team were very generous in sharing their knowledge and experience for achieving optimal welding outcomes.

Image 32: The Fellow at work with the team of welding specialists at Siro Lasertec in Pfortzheim Germany.

Practical steps for the operation of laser welders:

a. Choose parameter settings:

» According to the individual application, using the touch screen.

» Inexperienced welder users can begin with the pre-set memory settings.

» The safest option is to select parameter settings in the lower ranges, especially for power. If your parameter settings are too low, you will notice that the weld is ineffective and no damage will have been done. If your energy levels are too high for the particular application, then the laser beam may blast holes in the item.

b. Position the foot pedal to avoid the need to look down again.

c. Adjust microscope:

» Remove right ocular, adjust focus dial until the cross-hair appears to be at its sharpest focus

» Replace it.

» Looking into the binocular eyepieces, adjust the left ocular so that the cross-hair image is again at its sharpest.

» The view should appear to have a single circular rim, the eye pieces can slide in or out for distance between eyes adjustment.

d. Orientation for welding:

» Placing the item for welding into the chamber, positioned under the microscope

» View the item through the microscope and move the item to find the exact position where it is in sharpest focus.

» Orientate the item to allow the laser beam to most directly access the spot to be welded. That is, the laser will not go around corners or travel through layers.

» Position the centre of the cross-hair onto the exact point to be welded, taking care not to lose focus.

e. Welding:

» Using the touch screen, select the “active” phase. The “inactive” phase is to allow for safe opening of the chamber. Most welders indicate this with a colour change on the screen.

» Depress pedal to shoot the laser beam for an initial trial weld. See, hear and possibly feel the heat of the weld take place.

» Assess the quality of the weld. The weld spot should appear like a relatively smooth, possibly rippled puddle. If it is too pitted, depressed and crater like, or pointy, it will be too brittle rather than a strong and homogenous weld.

» Make adjustments required to the parameters chosen for best welding results. An easier way to change the parameter settings now is using the switches inside the chamber, closer to your hands.

Image 33: Silvio Valenta, Director, using a welder at Siro Lasertec.

To be a truly skilled craftsperson takes considerable time and practice, but by the end of the second week of intensive training, the Fellow had enough understanding of the process, parameter settings and applications of the technology, to use the laser welding equipment with confidence. The Fellow has gone on to use a laser welder as an everyday part of her own jewellery making and repairing practices and can no longer imagine being in a workshop without one.

Image 34: Laser welders ready for shipping around the world at Siro Lasertec, Pfortzheim.

Location 5: Schmuckmuseum, Pforzheim, Germany

The Pforzheim Jewellery Museum is the only museum in the world exclusively devoted to jewellery. Around 2,000 exhibits show jewellery art spanning six millennia, dating from prehistoric times to present day. The collection boasts elaborately and finely crafted jewels of Greek and Etruscan antiquity, sumptuous jewels of the Baroque, important pieces from the Art Nouveau and a renowned collection of contemporary designer jewellery. On display are Watchmaker and Goldsmith art documents from the 17th to the 19th century, together with a section on the history of the Pforzheim jewellery industry. Just five minutes away, the Technical Museum of the Pforzheim jewellery and watch industry, gives vivid insights into aspects of production.

Image 35a, Image 35b and Image 35c: Some of the jewellery / object d'art on display at the Schmuckmuseum.

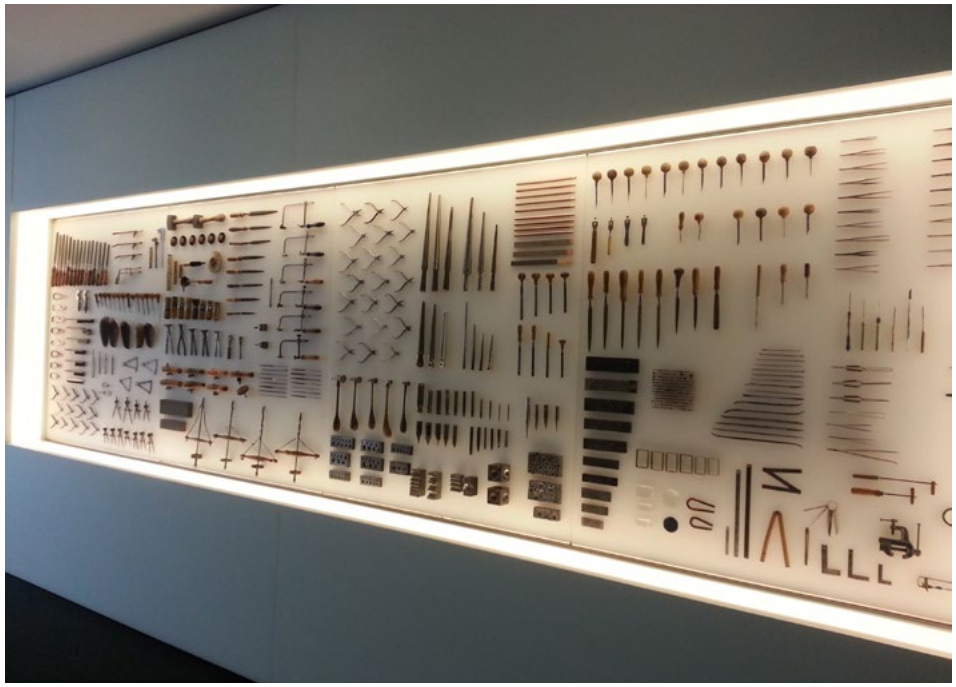


Image 36: Historic display of jewellery hand tools at the Schmuckmuseum.

This is the one of the most significant jewellery collections in the world. The display clearly represents each item in chronological order, with details of providence, cultural and historic significance with reference to design development. This is a "must see" for every serious jeweller.

"The city of Pforzheim has always been conscious of its cultural and economic tradition as a European centre for jewellery and watches"

The Fellow was so inspired by the collection that she is keen to steer the Gold and Silversmith's Guild of Australia towards creating something that similarly documents the historical progress of Australian jewellery design. This was not of course the original aim of the Fellowship but a bonus result.

The strong impression the Fellow garnered from this visit is of an entire town built around the jewellery industry. Just about every business there seems to be connected to jewellery and the Schmuckmeseum can be considered the town's crowning glory.

Image 37a and Image 37b: The Fellow at the historic remains of the original orphanage which was established in 1767 by the Jewellery and Watch Industry of Pforzheim. This was considered to be the world's first ever jewellery factory, and marked the beginning of modern production methods.

Location 6: Philippe Pfeiffer Jewellery, Limmattqui, Zurich, Switzerland

Contact: Philippe Pfeiffer

Image 38a and Image 38b: Phillippe Pheiffer with some of his jewellery at his Zurich store.

Image 39: The store front of Phillippe Pfeiffer Jewellery.

Philippe Pfeiffer is a high-end jewellery retailer and workshop located in the prestigious Limmatquai tourist area of Zurich. Pfeiffer is a goldsmith who prides himself on being at the cutting edge of bespoke jewellery design and making. He stays directly involved with designing for clientele as well as actual fabrication in the workshop. Pfeiffer's workshop has five craftspeople, and he actively trains new goldsmiths and gives enormous creative freedom to his staff.

Pfeiffer was extremely generous in sharing his knowledge and experience in a day of mentoring with the Fellow. Discussions and demonstrations included general jewellery business strategy and comparisons between European and Australian jewellery buying preferences. Noble learned of the techniques and skills that Pfeiffer has incorporated into his practice.

Pfeiffer's workshop has used both pulse arc and a laser welder for approximately 20 years. He could not imagine being without it and was genuinely shocked that they are not yet universally used in Australia. Demonstrations given to the Fellow included equipment tools and machinery seconded from other industries that were not traditionally used for jewellery making at all.

Pfeiffer has an experimental, innovative approach to his craft. When he found a technique he liked, he was able to incorporate it as a foundation of his signature designs. Noble talked with the jewellers in the studio and was surprised at how much creative freedom even the apprentices were given to develop their own designs and techniques.

Pfeiffer shared strategies involving use of raw materials, new technologies and pricing; elements that assist in keeping his designs fresh, gives his bespoke design business a point of difference and consequently enables him to support his own and his staff's continual creative development.

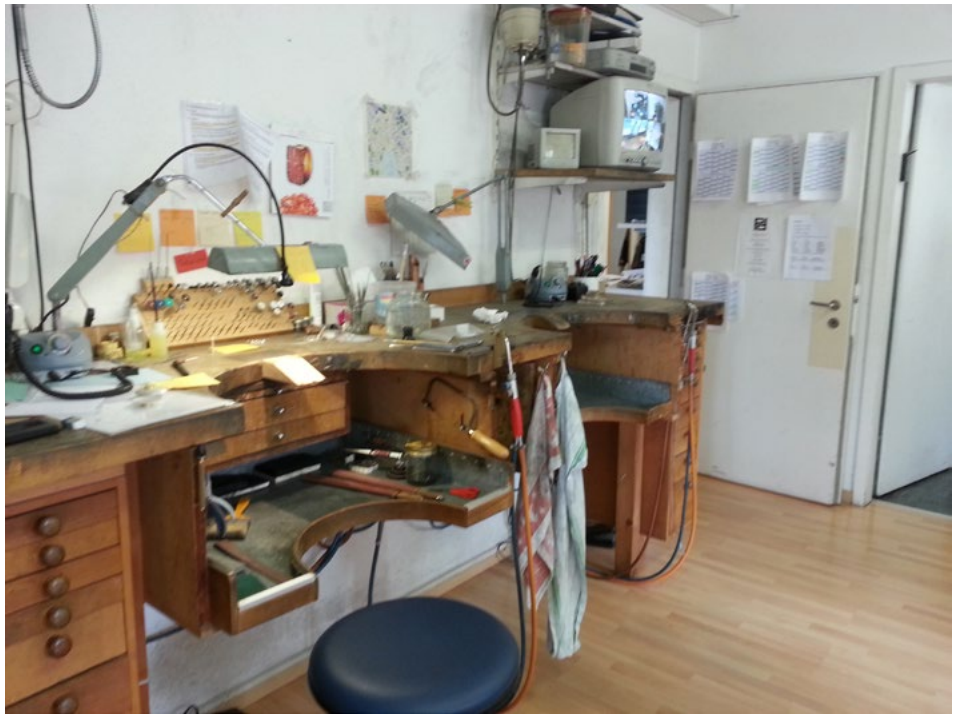


Image 40: The Philippe Pfeiffer Jewellery workshop.

Image 41: Jewellery apprentice and his work in progress at Phillippe Pfeiffer Jewellery workshop.

Sharing knowledge and training others, Pfeiffer's management style enables staff to creatively extend themselves at his expense and then down the track the rewards are mutual. It was inspirational to meet such an innovative craftsperson who is also extremely successful at his business and yet so generous in sharing skills with others.

A skill underpinning the impressive body of work for this company is laser and pulse arc welding. Many of the designs would not be technically possible without the flexibility their use generates.

In Europe the appreciation for handcrafted and bespoke items is greater and more culturally ingrained than in Australia. Craftspeople have historically been held in high regard, which has carried into the present day. The proliferation of chain stores and Chinese made goods that we have in Australia, was also noticeably absent in Europe.

Since visiting Pfeiffer's business in Zurich during this Fellowship, it is worth noting that his business has now moved to London.

Image 42a, Image 42b and Image 42c: Examples of the jewellery designed by the junior staff at Philippe Pfeiffer Jewellery.

6. Knowledge Transfer: Applying the Outcomes

The goal of this Fellowship was to discover the benefits of electronic fusion welding and then share the knowledge and techniques with industry.

Melbourne Polytechnic is the ideal training facility for welding skills to be shared in Victoria, but there is currently no welding equipment at the school. To assist the Fellow to pass on the skills and techniques of fusion welding, the Rofin Company installed a laser welding machine at the school on loan for three months after the research trip for this Fellowship. During this period, the teachers and students took up the opportunity for demonstrations and practice using the welder.

The Fellow has scheduled two industry training presentations to share information on fusion welders with the broader jewellery community. These presentations will be promoted to all peak industry groups, including the Gold and Silversmiths Guild of Australia, the Gemmological Association of Australia, and the Jewellers Association of Australia.

Extracts from this research report will be provided to the all industry journals and social media networks with the goal of raising awareness and understanding about the benefits of fusion welding.

The use of Pulse arc and Laser welding equipment has the potential to improve and revolutionise the practice of local jewellers. Huge savings in time and money as well as the freedom to unleash some creativity await jewellers who embrace this technology.

7. Recommendations and Considerations

Consider Establishing an Education, Training and Industry Working Group:

The Fellow recommends the formation of a working group including all industry and education groups mentioned below to improve awareness between industry and educators about changes in technology and needs of industry.

» Melbourne Polytechnic and Royal Melbourne Institute of Technology

» Department of Education and Training (Higher Education and Skills Group)

» Jewellers Association of Australia

» The Gold and Silversmith's Guild of Australia

» Manufacturing Skills Australia

» The Gemmological Association of Australia

Investigate Training Technology Needs and Investment:

Examine the cost of purchasing electronic fusion welding technology, specifically a pulse arc welder and a laser welder to enable skills training in welding technologies.

Examine Current and Future Training Needs:

Examine the current Units of Competency within the National Training Packages to determine whether the essential skills of fusion welding fall within the units. The courses to consider are:

» Certificate III in Jewellery Manufacture (MEM30605)

» Diploma in Jewellery and Object Design MEM50311

» Advance Diploma in Jewellery and Object Design MEM 60211

» Specific examples of Units of Competency that that may incorporate these skills are:

» MEM19033A Create Silversmithing Objects

» MEM18002B Use power tools/hand held operations

» MM18003C Use tools for precision work

» Suggest MEM05006B 'perform brazing/ or silver soldering' be changed to 'perform soldering/or welding'.

Examine the possibility of introducing a Certificate IV or other appropriate higher qualification in Jewellery Making. This is already an accredited National Training Package and would overcome the problems of:

» Crowded course content in current qualifications

» A perfect way to incorporate the many new technologies, such as CAD and laser engraving, into the recognised industry qualifications

Offer Master Classes:

Source and draw on individual expertise to initiate the scheduling of short term 'Master Classes' in specialised skills. Fusion welding classes, such as those offered by the Fellow, could continue. But structured training in other specialised skills could also be explored.

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9. Acknowledgements

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Awarding Body – International Specialised Skills Institute (ISS Institute)

The ISS Institute exists to foster an aspirational, skilled and smart Australia by cultivating the mastery and knowledge of talented Australians through international research Fellowships.

The International Specialised Skills Institute (ISS Institute) is proud of its heritage. The organisation was founded over 25 years ago by Sir James Gobbo AC CVO QC, former Governor of Victoria, to encourage investment in the development of Australia's specialised skills. Its international Fellowship program supports a large number of Australians and international leaders across a broad cross-section of industries to undertake applied research that will benefit economic development through vocational training, industry innovation and advancement. To date, over 350 Australian and international Fellows have undertaken Fellowships facilitated through ISS Institute. The program encourages mutual and shared learning, leadership and communities of practice.

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- Preparing a detailed report for distribution to government departments, industry and educational institutions
- Recommending improvements to accredited educational courses
- Delivering training activities including workshops, conferences and forums.

The organisation plays a pivotal role in creating value and opportunity, encouraging new thinking and early adoption of ideas and practice. By working with others, ISS Institute invests in individuals who wish to create an aspirational, skilled and smart Australia through innovation, mastery and knowledge cultivation.

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» The Gemmological Association of Australia

» Genesis Jewellery, Ian Dun, Director, Melbourne, Australia

» The Gold and Silversmith's Guild of Australia

» The Jewellers Association of Australia

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» Larah Nott, Gold and Silversmith

» Oblo Jewellery Michael Oboler, Director, Melbourne, Australia

» Phillippe Pfeiffer Jewellery, Phillippe Pfeiffer, Director

» Rutherford Fine Jewellery, Wesley Rutherford, Director, Melbourne, Australia

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» Lisa Sennhauser and family

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» Refraction Jewellery, Jake Coughlin, Director, Queensland

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