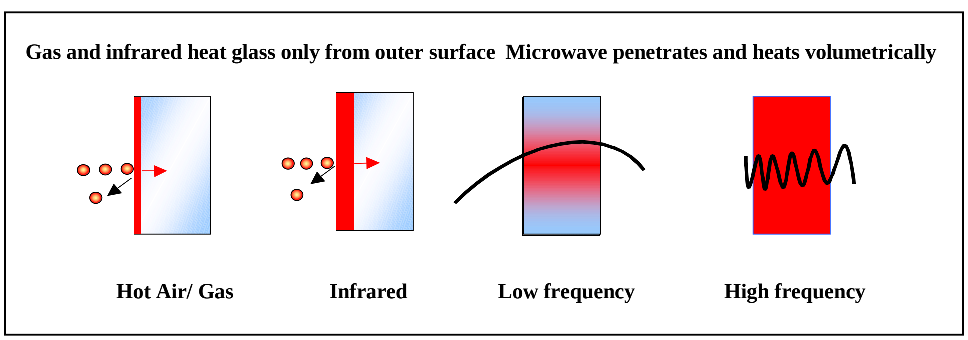
A new Way of Heating Glass

High-frequency Microwave provides on-demand processing

By Vlad Sklyar, Ph.D.

Everyone in the glass business knows how space and time-intensive melting and processing glass is, where every degree or minute saved is valued. Long furnaces, hours in autoclaves, huge glass melting tanks…A new way of heating glass promises to change all that with the possibility of single-site heating and bending; continuous line, autoclave-free laminating; and almost on-demand glass melting that transforms tube and fiber production into a rapid, flexible process. The big production problem with conventional heaters is that glass cannot be heated fast without cracking from the internal temperature differential. The maximum heating rate for a 4 mm glass sheet, for example, is 6^0C/s-10^0C/s. Even this low rate requires a high uniformity heat source--not a simple task--because conventional energy sources like infrared or hot air are highly non-uniform in themselves. To achieve high production, billions of BTUs are wasted by tunnel furnaces that heat rollers, shelves, walls, and, indirectly, whole plants. Slow heating also has its own drawbacks, like optical and geometrical distortion, mineral leaching, loss of flatness and strength, and destruction of coatings, to name a few. So a radical departure from this whole model would be needed to break through to better thermal processing.

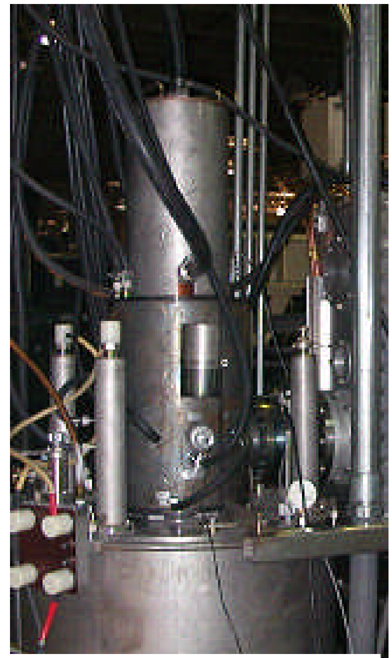
There aren't many choices here: laser, plasma, electron beam, and microwave. Of these, microwave is the most promising because it can heat large objects, penetrate inside and create a smaller temperature differential, permitting a higher heating rate and efficiency. A whole spectrum of industrial microwave equipment is available: ranging from megahertz to dozens, and even hundreds of gigahertz. However the track record of low frequency microwave is disappointing: high non-uniformity and still low efficiency. Besides, the low absorption by glass for this kind of microwave translates into megawatts of power needed to bring it to an industrial scale, to produce windshields, windows, and other large glass products. Achieving this power for RF or conventional industrial microwave (2.45GHz) is nearly impossible and cost prohibitive.
That leaves high frequency microwave. Fortunately, it's much better in interacting with non-metallic materials and offers efficiencies higher than 80% for glass.



Another advantage is that this kind of microwave can be spatially configured, as in, a beam. This opens a whole new world of possibility: microwave that can be targeted at the product, with no heat where it's not (walls, rolls, etc), high power/heat density and, as a result, hundreds of degrees per second heating rate. Specially designed mirrors provide very high uniformity (3-4%) or controllable non-uniformity over large areas. This "configured" microwave energy can be focused down to a few millimeters or spread over dozens of square feet; rastered or even split.

High frequency concentrated microwave for industry became available with the development of the gyrotron. This 5-6' long, 100-150 lbs metal tube generates a microwave beam around ½" in diameter, with CW power from a few KW to 100 KW and more. The gyrotron is usually attached to a customized work chamber that offers all needed shielding and can be configured for large, small and variable size products in fully and semi-automated lines. Because the microwave beam can be split, one gyrotron can process glass products from several sides simultaneously or provide thermal treatment for several production lines at once. The gyrotron beam installation has a small footprint and can easily be installed into existing lines with little down time. The safety model is not complex and is responsive to production line configuration. Site monitors and employee awareness training make it quite operator friendly.

This way of heating offers a range of capabilities that have not previously been available in thermal processing. Unique selective heating of one material or layer while leaving others cool, focusing energy only where needed, and heating one layer or material through an adjoining layer lead to advanced product formulations. Here are some examples of where this new mode of thermal processing can be of great advantage.



A 40 KW industrial gyrotron

Shaping/bending Faster gyrotron heating means reduced costs and space consumption and also improved products. Controlled power distribution over the glass and rapid heating brings high temperature only to the local areas that need it, protecting optical properties. This also facilitates manufacturing of new designs of vehicle glazings, for example, with complex geometries, and superior quality.

Coated glass Low E-coatings are problematical at best, when heated by infrared. Microwave beam heating avoids these problems by not interacting with ultra thin coatings at all. Therefore using the beam eliminates the main problems of processing coated glass: long heating and coating damage.

Tempering thin glass Exclusive, controlled temperature distribution inside a glass sheet is now possible in the whole temperature range that is appropriate for processes where increasing and reducing glass temperature is desired. Air is transparent for the beam. Consequently, the temperature differential between the outer glass surfaces and midplane during quenching needed for tempering can be realized with selective, simultaneous, heating of midplane and cooling of surfaces. As a result glass thinner than 2mm can be fully heat tempered.

Laminating A strip-shaped beam moves quickly and continuously over the adhesive film, heating it through a roller that moves synchronously with the beam. Air is squeezed from under the film and the need for autoclave-type furnaces is eliminated. The technology makes high-yield continuous laminating lines feasible.

Local firing of coatings and frits Controllable, exclusive heating of a thin local surface layer can also be performed using this method. The beam or part of it can be focused in the required area. Heating the entire glass to high temperature is avoided, keeping it flat, unmarked and optically suitable.

Sealing glass The gyrotron beam can be targeted exclusively on the seal, processing it rapidly, without heating the entire product. Heating fast and locally also allows joining tempered glass sheets without loss of temper. Despite the high processing temperature of commonly used frits (400-500C), the post-processing level of temper remains above 90% and above 75% in the processing area, because processing time is so short.

Melting The gyrotron offers a unique solution to many of the problems associated with glass melting for tubes, glass fiber and the like. In this process, raw glass mix is continuously melted, virtually on-demand, with only a small reservoir of molten glass being maintained. Therefore, cleaner glass is produced with minimal bubbling; shutdown for maintenance or mandrel changes is quick and easy (without significant waste) and high temperature accuracy can be sustained The problems of large glass tanks are minimized in all aspects, from tank damage, to managing the flow of a large quantity of molten glass. Massive glass tanks and heaters are replaced and a small gyrotron installation can meet and exceed the demands of a high volume production line.

Glass cutting Simultaneous heating and cooling not only tempers thin glass, but cuts glass as well. By configuring the gyrotron beam to a local area or along an entire separating path, in less than a second, temperatures great enough to create compressive thermal stress are created, cleanly separating the glass. Speeds can be rapid, faster than mechanical cutting. Flat, non-flat and tubing glass can be cut rapidly, with a high quality cut. All kind of glass, even with low thermal expansion, like quartz, can be separated by this technology.

Parting glass tubes The beam's high power density and ability to heat volumetrically allows melting glass tubes (pharma and scientific glass) in a fraction of a second without significantly heating the whole tube. The result is a vial virtually without the sodium leaching contamination associated with conventional production methods.

Fiberglass-based composites Selective, controllable heating of composite components to different temperatures is possible with the gyrotron beam. This allows optimal fiberglass temperatures to be maintained during curing, resulting in high quality composites.

Drying fiberglass. Because water absorbs gyrotron energy faster than glass and because of the beam's high power density, fast and efficient drying, even drying at the speed of winding is possible, to any degree of dryness. Power density can also be controlled to respond to changing moisture levels during processing.

How do process heaters compare?
In efficiency, it's ability to heat at hundreds of degrees per second, high uniformity or controlled non-uniformity, selective heating and cost effectiveness, the gyrotron is the high performer that might over time replace other heaters or work along with them to enhance glass processing.

	Gyrotron	Hot air/gas	Infrared	Low frequency mw
Heat efficiency, %	80-90	5-30	3-25	10 - 40
Heating rate up to, ^{0}C/sec	1,000+	20	30	100
Uniformity, %	2-3	7-10	5-7	6-10
Ability to heat selectively	Yes	No	very rare	uncommon
Capital costs per product	1	3-4	3-5	Not used in mass production
Operating costs per product	1	5-10	5-10	

Is this the twenty first century's new tool for glass processing? With its range of previously-unavailable capabilities, it may well be. For more information see the website www.gyrotrontech.com (email technical@ gyrotrontech.com) or contact Gyrotron Technology Inc. at 215-826-8415