Glass Music World
WINTER 2004

Acoustics of Glass Musical Instruments

– by Thomas D. Rossing –
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Ten years have passed since I published a paper entitled "Acoustics of the glass harmonica" in the *Journal of the Acoustical Society of America* [1]. That paper discussed the physics of the instrument we all love so well. It was reprinted in the Summer/Fall and Winter/Holidays issues of *Glass Music World*, and, judging from the feedback I received, fairly well received by readers of that publication. Many performing musicians have discovered that understanding the physics of their musical instrument (whether it is a violin or an armonica) is a great help in improving their playing technique as well as developing "new sounds" in their instrument. Performers, as well as scientists, love to experiment, and science can profitably guide their experiments.

More recently I wrote a book on the *Science of Percussion Instruments* (World Scientific, 2000) which includes a chapter on Glass Music Instruments [2]. A few GMI members have commented on this chapter, and I would welcome comments from others. In the past ten years, there have been a few published reports on scientific research on glass musical instruments but not as many as might have been expected. Most of them have dealt with tuning of wine glasses, shatter at high amplitude, glass versions of traditional wind and percussion instruments, and novel glass instruments.

In this article, written for both performers and experimenters, we will review the science of the glass harmonica and other types of glass musical instruments.

Vibrational modes of a wineglass

In musical instruments, sound is produced by one or more vibrating systems, such as the vibrating string and soundboard of a violin, the vibrating air column of a trumpet, or the vibrating membrane of a drum. A discussion of vibrating systems found in musical instruments is included in my textbook *Science of Sound*, written especially for musicians.

It is very useful to describe vibrating systems in terms of *normal modes* of vibration. A normal mode describes the shape of a vibrating system at one of its natural frequencies. In a violin string, the normal modes describe the back and forth motion of the string in one or more segments separated by *nodes* or points at which the motion is minimal (unfortunately, the terms *nodes* and *modes* sometimes get confused). In the fundamental mode, the entire string moves in one direction; in the second mode there is a node at the center and the two halves

see ***ACOUSTICS,*** *page 2*

Paris Festival '05
– Program and Information –

The museum in Cité de la Musique

Thomas Bloch is now completing his planning and organizing of the Glass Music Festival to be held in and around Paris in early February. He is now working out the final details and will be on tour in Sydney, Australia for most of the month of January.

For the festival details as of 12/16, please see:

FESTIVAL, page 4-5

— **ACOUSTICS** *from page 1* —

move in opposite directions. In a vibrating string, the modes are very nearly harmonic (that is their frequencies are multiples of the fundamental frequency).

The normal modes of a two-dimensional plate or a three-dimensional shell are more complicated than those of a one-dimensional string. Fortunately, only the lowest couple of modes of a wineglass are of musical importance, and these are relatively simple. The first three modes are shown in Fig. 1, which is reproduced from my earlier article in GMW. The nodes appear in white, and the fringes provide a contour map of the way the glass vibrates. Note that the glass is divided into 4 to 8 vibrating segments that move in opposite directions. The vibration amplitudes are maximum at the rim.

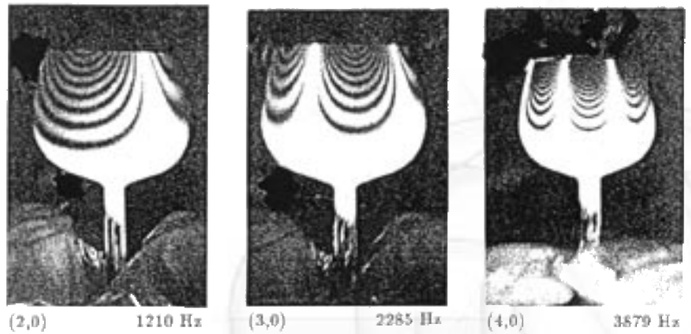

Fig. 1. Holographic interferograms of 3 modes in a wineglass. [1].

The modes shown in Fig. 1 are not harmonic. The frequencies of the first six modes [1] are in the ratios of approximately 1 : 1.89 : 3.21 : 4.88 : 6.96 : 9.23. Striking the glass with a mallet will excite all of these modes and more, but rubbing the rim with a wet finger excites only the lowest mode and its harmonics [1]. (This fact is not clear in some articles about glass harmonicas).

Each point on a vibrating wineglass moves differently as it vibrates. The holographic interferograms in Fig. 1 show only the axial motion (motion normal to the surface of the glass). At the nodes for normal motion, the glass moves tangentially. In the fundamental (2,0) mode, the maximum tangential amplitude is half the normal amplitude, as shown in Fig. 2. This means that the glass can be excited by applying either a normal or a tangential force.

Armonica bowls

Vibrational modes of two Finkenbeiner armonica bowls are shown in Fig. 3. As in the wineglass in Fig. 1, the fundamental tone is determined by the (2,0) mode which has 4 nodes around the rim of the bowl. The larger bowl has a fundamental frequency of 550 Hz (C#5), and the three modes have frequencies in the ratios 1 : 2.43 : 4.36. The smaller bowl has a fundamental frequency of 1120 Hz (C#6) and the modal frequencies are in the ratios 1 : 2.54 : 2.55 : 4.61. Two modes in the smaller bowl have nearly the same frequency constitute a "doublet" mode, and they result from a slight inhomogeneity in the glass. Note that one mode in the doublet pair has anodes where the other mode has maximum vibration. This behavior is often observed in bells and other systems with circular symmetry.

The holographic interferograms in Fig. 3 were made with our electronic TV holography system, which is a rapid and accurate tool for determining modes of vibration in musical instruments (considerably faster than recording them on photographic film as in Ref. 1).

Sound of armonica and glass harp

Since the vibrational modes of glasses or bowls have both normal and tangential components, they can be excited by either a normal or a tangential force. Glass harmonicas are usually played by rubbing the rim of the glass or bowl tangentially with a wet finger, but striking the glass with a mallet or bowing it radially with a violin bow also sets it into vibration.

Rubbing a glass with a wet finger excites vibrations in the glass through a "stick-slip" process, much as a moving violin bow excites a violin string. During part of a vibration cycle, the rim of the glass at the point of contact moves with the finger; during the balance of the cycle it loses contact and "slips" back toward its equilibrium position. This results in a sound that consists of a fundamental plus a number of harmonic overtones. The location of the maximum motion follows the moving finger around the glass. Sound spectra for a wineglass, a brandy snifter, and an armonica bowl excited with a wet finger, a yarn-wrapped mallet, and a violin bow are shown in Ref. 1.

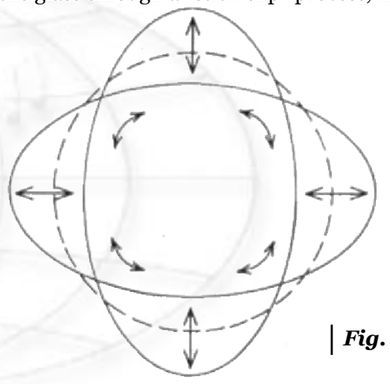

Fig. 2

As the finger moves around the rim of a wineglass, the region of maximum vibration follow the moving finger, resulting in a sound that pulsates with about 4 to 8 beats per second, depending upon the speed of the player's finger. [1].

Although the vibrational modes of a wineglass do not have harmonic frequencies, it is possible to tune them to a harmonic relationship by grinding away glass or adding mass in certain places. Computer programs can be used to determine the locations for doing so [3]. However, that is mainly of academic interest, since, as we pointed out, only the fundamental mode is excited in normal playing.

***ACOUSTICS** continues on page 7*

PRESIDENTIAL NOTES

By the time you receive this newsletter, the Paris Festival will be less than a month away. Thomas Bloch has done an outstanding job of planning and organizing this festival and at times it has been very difficult for him. You may recall that after he had made arrangements for the festival with the Director of the Cite de la Musique, that Director retired and he had a long delay before the new Director had firmed up his plans for the organization. Thomas has done an amazing job considering that he has been touring the world giving concerts at the same time that he has been doing his planning.

Thomas has taking numerous steps to minimize the cost of the festival to GMI and its members. These include negotiating for good rates and using his own time, efforts, and resources. These steps along with the fact that we have not had a festival in five years led to our being able to eliminate the normal festival registration fee for members for this particular festival. Registration fees were charged for both the 1997 and 2000 festivals. In the future, we will undoubtedly have to go back to charging registration fees for festivals, especially if we have them more frequently. Three members have corresponded with me about their desire to have festivals in their communities in the future and this issue will be taken up at the GMI organization meeting in Paris. Once the possibilities are established with details, we will poll the entire membership to get their preferences.

On another note, the feature article in the last issue on the "Tutor for the Musical Glasses" was not complete. We are including the completed text as an insertion in the issue.

Finally, I wish to point out that the 2005 dues are now due and if you would send them in to Alisa in a timely manner it would be greatly appreciated. The dues allow us to print and mail these newsletters as well as helping us reduce the costs associated with festivals.

GMI Happenings

– By Elizabeth Mears –

As our February festival in Paris approaches, I assume that our membership is entertaining the public with glass music around the world.

From **Lynn Drye**, Prescott, Arizona, we learn that she gave two performances of the Johann Friedrich Reichardt "Rondeau in B-flat Major for Glass Harmonica, String Quartet, and Double Bass" with the Prescott Strings in November. The performance was very well received by both the audience and the members of the Prescott Strings. She now has the entire score notated (from manuscript) and will be sending it to Thomas Bloch for inclusion in the GMI Library collection.

Several historical museums in the New York area have had the pleasure of performances by **Cecilia Brauer** this fall. Among them are King Manor, home of Rufus King, one of the signers of the Constitution, and several Long Island libraries. 2005 promises to be a very active year for Cecilia. She has begun her orchestra rehearsals and performances with the Metropolitan Opera and will be extremely busy through the middle of May. Also, her school performances are starting to book in and she especially enjoys doing those.

In October and November, **Thomas Bloch** was asked to record several movie scores with the glass harmonica. "Vampires 3 : The Turning" recorded with the Czech National Orchestra, and before that a new movie by Sally Potter called "Yes", in duet with guitarist Fred Frith. During his stay at the San Francisco American Conservatory Theater, Emilie Simon and Universal Barclay records, asked him to record for "La Marche de l'Empereur", a TV documentary. That is the theater where he played "The Black Rider" by Tom Waits, William Burroughs and Bob Wilson, with Marianne Faithfull as the main singer, a French young female popular singer who won the "Victoire de la Musique" last year (the equivalent of a Grammy Award). Then, Rene-Marc Bini proposed that he record "Nom de code DP", a TV fiction based on the preparation of an attack by terrorists. In December, he recorded for the soundtrack of a new musical, "Fantomas". He played the Mozart K.617 and various works in Holland, played for the 20th anniversary of the TV channel Canal + in November, and will spend all January in Sydney Festival, still with Waits, Burroughs, Wilson and Faithfull. Thomas has recently released four new CDs, including two with the glass harmonica :

- MOZART / COMPLETE QUINTETS VOL. 4, Ensemble Villa Musica, Adagio and Rondo K.617; Ref : MDG 304 1182-2, label : Dabringhaus und Grimm / MDG Gold.
- VOX IN VITRO, an operatic thriller, composed by MICHEL REDOLFI; Ref : Sig11025, label : Signature / Radio France;
- MUSIC FOR ONDES MARTENOT played by Thomas Bloch (ondes Martenot) accompanied by 70 various soloists and orchestra; works for ondes Martenot solo, 9 ondes , double concerto with orchestra, chamber music and electronics by Messiaen, Martinu, Bloch, Cooper, Redolfi, Rolin, Touchard, Wisson; Ref : 8.555779, label : NAXOS
- MISSA CANTATE, composed by Thomas Bloch for male soprano and symphony orchestra, a 45 minutes work in 10 parts; published on Thomas own label (TGB), it will be published by Naxos in 2006 together with other works he has composed.

GLASS MUSIC FESTIVAL / PARIS 2005

3. - 6. February 2005

MAIN FESTIVAL LOCATION

CITE DE LA MUSIQUE / MUSEE DE LA MUSIQUE
221 avenue Jean Jaures
75019 PARIS
France
Metro (subway): Porte de Pantin (line 5)
When you are in avenue Jean Jaures, you are facing the "grande halle de la Villette" (a huge 19th century market in glass and metal), Cite de la Musique is the modern building on the right, with "Cafe de la Musique" at the corner. The first meeting will be there, in the main hall (see the planning for the time).

FOR URGENT CONTACT

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HOW TO GO TO THE CITE DE LA MUSIQUE

If you arrive by plane, you can take:
1 - A taxi: you can give the address to the driver and add that "Cite de la Musique" is located "Porte de Pantin, parc de La Villette". Without traffic jam, the trip must costs very approximatively 35 to 60 Euros (or more) according to the airport and the traffic jam. During rush hours which are from 7 am to 10 am and from 4 pm to 9 pm, it can take 2 or 3 hours to arrive rather than 20 to 30 minutes without problem.
2 - A subway: it must be about 3 times less expensive (or less by traffic jam) and it is about 1 hour. Buy a ticket for "Paris Centre" and keep it. It will be necessary for connections (don't buy another ticket) and to go out of the station. Note that in the metro or RER, the last station of the line is always indicated and gives you the direction. You can ask a free map when you buy the ticket but you'll also receive one when we'll meet. You have two airports in Paris.
a -From "Roissy Charles de Gaulle" airport, take the fast metro called RER (line B) to Paris. Stop in station "gare du nord". Then, see point c below.
b - From "Orly" airport, take the shuttle which goes to the connection with the RER (line B) in a town and station called "Antony". Stop there and take the RER (line B) to Paris. Stop in station "gare du nord". Then, see point c below.
c - In "gare du nord", stay underground and use the same ticket via automatic doors to take Metro (line 5 also called M 5), direction "Bobigny". 5th stop is "Porte de Pantin" when you go out.

If you arrive by car, several possibilities but always keep in mind that you have to take "peripherique", the highway around Paris and go out at "Porte de Pantin" which is North East of Paris. The back side of "Cite de la Musique" is along the "peripherique". It is located approximatively at the same distance from the connection between "peripherique" with A 1 ("Autoroute" - highway from North of France) and "peripherique" with A 3 (highway from North east). If you see that you are in the wrong way, you can easily go out at the next "porte", go under the "peripherique" and take it again in the opposite way. Or, if you are not sure, you can continue and in any case you'll cross "Porte de Pantin", as it turns all around Paris (don't turn several times... it is a joke).

PLANNING

2. FEBRUARY 2005 (arrival)
day: arrival in Paris

3. FEBRUARY 2005 (bus tour / opening / installation Cite de la Musique)
12pm: meeting in the main hall (rue musicale) / Cite de la Musique
1pm - 4pm: bus tour in Paris
4pm - 5pm: meeting in the main hall to receive the Festival folder
4.30pm - 5.30pm: glass instruments installation in the Museum (for those who are concerned)
8pm: concert Thomas Bloch (glass harmonica) - Clemens Hofinger (seraphim) - Ensemble Stradivaria - Mozart, CPE Bach, Roellig, Naumann... / amphitheatre - Cite de la Musique, Paris

4. FEBRUARY 2005 (Cite de la Musique)
9am - 1pm: conferences in "salle des colloques", Cite de la Musique
1pm - 2pm: meal or end of instruments installation in the Museum for those who are not ready
2pm - 5pm: concerts in "Musee de la Musique", Cite de la Musique. Evening: free

5. FEBRUARY 2005 (Cite de la Musique)
9am - 1pm: conferences in "salle des colloques", Cite de la Musique
1pm - 2pm: meal
2pm - 4.45pm: concerts in "Musee de la Musique", Cite de la Musique
4.45pm - 5.30: instruments out of the Museum
8pm: dinner in the center of Paris

Thomas Bloch with Bernard Baschet

6. FEBRUARY 2005 (Baschet's factories)
10am - 12am: cristal Baschet concert and visit of the first Baschet's factory, rue Jean de Beauvais, Paris
12am: meal in the factory (a tradition established in 1952 by Francois Baschet and still active)
2pm: train to St Michel sur Orge
3pm - 6.30pm: Bernard Baschet, cristal players and composers in the second Baschet's factory, St Michel sur Orge
6.30pm: champagne party and "buffet campagnard" in Bernard Baschet's factory, St Michel sur Orge
End of Paris 2005

7. FEBRUARY 2005
IMPORTANT: note that the Museum is closed every Monday (so it is on the 7th of February). If you leave Paris this day and have an instrument, you must take it with you at the hotel on Saturday 5. evening (4.45pm to 5.30pm). If you leave on the 8th afternoon or later, we can certainly find a place to leave it until you leave.

LECTURERS - PERFORMERS - LISTENERS

41 have confirmed
31 will play and/or speak
27 will assist to* the complete festival
14 will assist to* a part of the festival
* Note: Those used to only English should read "assist to" as "attend".

CONCERTS
22 PERFORMERS - some will give lectures during concerts
(10 CONCERTS : 1 in Cite de la Musique, 6 in Museum, 3 in Baschet's factory)

Pierre-Yves Berenguer (France) - composer
Michel Bertier (France) - composer
Peter Bennett (USA) - musical glasses
Thomas Bloch (France) - glass harmonica, cristal Baschet
Catherine Brisset (Paris, France)
+ 2 musicians - cristal Baschet, strings
Jean-Claude Chapuis (France)
+ 3 musicians - MusiVerre - various glass instruments, harp...
Michel Deneuve (France) - cristal Baschet
Jacques Dupriez (Belgium) - viola, violin-baryton
(duet with Thomas Bloch)
Clemens Hofinger (Germany) - musical glasses
Sascha Reckert (Germany),
+ Philipp Marguerre (Germany)
+ Friedrich Kern (Germany) - various glass instruments, piano
Etienne Rolin (France / USA) - composer, CD label director, publisher, musician
Dean Shostak (Williamsburg, USA) - glass violin, glass harmonica
Ingeborg Stein (Germany) - cristal Baschet
Cathy Tardieu (France) - cristal Baschet

CONFERENCES
9 LECTURERS
(7 CONFERENCES : 6 in Cite de la Musique, 1 in Baschet's factory)

Bernard Baschet (France) - glass instrument maker
Carlton Davenport (USA) - Glass Music International President - "GMI organization meeting"
Jean Jourdheuil (France) - stage director
Stephane Leach (France) - comedian, glass musician, composer
Florian Lechner (Germany) - glass designer, glass musician
Thierry Maniguet (France) - acoustician, Paris Music Museum
Michel Redolfi (France) - composer, subaquatic glass music
Jody Rosen (USA) - writer, music historian
Stephane Vaiedelich (Paris - France) - director of the Paris Musical Museum laboratory

LISTENERS
14 listeners

Ralph Archbold
Marie-Claire Archbold (Ralph's daughter)
Liselotte Behrendt (Germany)
Peter Behrendt (Germany)
Christine Bloch (France)
June Davenport (USA)
Thomas J. Degnan (USA)
Douglas Lee (USA)

***FESTIVAL** continues on page 8*

— *ACOUSTICS* from page 2 —

Adding water

I am sometimes asked why adding water lowers the pitch of a vibrating wine glass, whereas decreasing the length of an organ pipe raises the pitch. The answer, as most readers will know, is that volume of air in the glass has almost no effect but the mass of the added water lowers the vibration frequency of the glass. Actually, adding water has rather little effect until the glass is more than half full, and thus it is not a good way to tune glasses. We found that filling glasses about ¼ full lowered the playing frequencies from 0.3% to 0.9% (5 to 15 cents). Filling them half full lowered the frequencies up to 6% (one semitone or 100 cents), but the water has considerable effect on the tone.

From Fig. 1 it is easy to see why modest amounts of added water have so little effect on the vibration frequency: the bottom part of the glass vibrates at very small amplitude.

Vibrations of the glass can set up some very interesting surface waves in the water (or wine) in the glass [4]. For a typical wine glass, surface waves travel at speeds on the order of 70 cm/s, comparable to walking pace. These slow wave speeds give rise to interesting waves of short wavelength around the edge of the glass which are similar in many ways to the "whispering gallery" waves Lord Rayleigh observed in the dome of St. Paul's Cathedral in London. At high amplitude, capillary shock waves can give rise to "spouts" of water as in Chinese "water-spouting" basins [5].

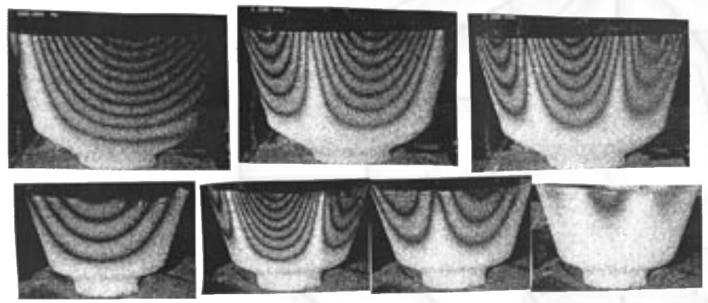

Fig. 3. Holographic interferograms of two Finkenbeiner armonica bowls. Frequencies in the upper bowl are 550, 1335, and 2398 Hz. Frequencies in the lower bowl are 1120, 2840, 2853, and 5167 Hz.

Verrophone

The verrophone uses tuned glass tubes rather than glasses or bowls. The vertical tubes are played by rubbing in much the same way as the wineglasses in a glass harp. The radiating surface can potentially produce a greater sound output if the entire tube vibrates. However, I know of no scientific measurements on the modes of vibration or sound radiation up until now.

The article in the Fall/Winter 2003 issue of *GMW* by Sascha Reckert, builder of verrophones, is very interesting reading.

Glass bells

Glass is a hard material that vibrates with relatively low damping loss, and thus it is quite a good material for making small bells. Furthermore, it has quite a low melting temperature, and thus it is easily shaped by standard glassblowing techniques. Although most glass bells are primarily decorative, the Sasaki Crystal company in Japan has produced tuned handbells similar in shape to bronze handbells.

Our friend Gerhard Finkenbeiner developed a bell synthesizer that uses quartz fibers whose vibrations are picked up by a sensor and amplified to produce bell-like sounds. Several churches in New England have "tower bells" that make use of Finkenbeiner's synthesizer.

Glass orchestras

The Sasaki Crystal company in Japan has produced a wide variety of glass musical instruments, including glass marimbas, glass chimes, glass trumpets, glass horns, glass alpenhorns, and glass flutes. I had the privilege of hearing a number of these instruments played at an international musical acoustics meeting in Tokyo in 1992, and I also enjoy a videotaped performance by their "glass orchestra."

The Kassel Glass Orchestra in Germany, led by Walter Sons, plays on a variety of glass percussion and wind instruments, including vases, bowls, glass spheres, dishes, sheets of flat glass, glass flutes, and glass tubes [6]

Eric Cadesky directs a group called Glass Orchestra. I have not heard them perform, but their website at http://www.vex.net/~rixax/GlassO/index.html includes photos of several of their instruments.

In Lund, Sweden, scientific glassblower Leif Lundberg has made instruments such as the trombone and tuba out of glass. His glass trombone is listed in the Guinness Book of Records as the world's only playable trombone made entirely out of glass.

Glass instruments of Harry Partch

Composer-inventor Harry Partch constructed his own musical world of microtones, elastic octaves, and percussion instruments. Partch's rich heritage of percussion instruments includes at least two glass instruments, which he called "cloud chamber bowls" and "mazda marimba." The tuned cloud chamber bowls are actually cut from acid arbors, while the mazda marima consists of light bulbs of various sizes.

Instruments of Jean-Claude Chapuis

French composer and instrument maker Jean-Claude Chapuis has developed a number of glass instruments. His glass balafon is a marimba-like instrument with a set of cylin-

FESTIVAL *continued from page 5*

LISTENERS (continued)

Shereen Khan (Doug Lee's wife) (USA)
Nevine Sabet d'Acre (France)
Carolinn Skyler (USA)
Werner Warmbier (Germany)
Sascha Reckert's guest
Philipp Marguerre's guest

OPENING CONCERT
3rd of February
(30 people)

Liselotte Behrendt
Peter Behrendt
Peter Bennett
Christine Bloch
+ two musicians
Catherine Brisset
+ two musicians
Jean-Claude Chapuis
+ one musician
Carlton Davenport
June Davenport
Thomas J. Degnan
Michel Deneuve
Jacques Dupriez
Friedrich Kern
Florian Lechner
Doug Lee
Doug Lee's wife
Philipp Marguerre
Sascha Reckert
Michel Redolfi
Etienne Rolin
Jody Rosen
Nevine Sabet d'Acre
Dean Shostak
Carolinn Skyler
Werner Warmbier

PARIS BUS TOUR
3rd of February
(19 people)

Liselotte Behrendt
Peter Behrendt
Peter Bennett
Carlton Davenport
June Davenport
Thomas J. Degnan
Friedrich Kern
Florian Lechner
Philipp Marguerre + guest
Sascha Reckert + guest
Michel Redolfi
Jody Rosen
Nevine Sabet d'Acre (?)
Dean Shostak
Carolinn Skyler
Werner Warmbier

ACOUSTICS *continued from page 7*

drical glass rods set over a box-like resonating chamber and played with mallets. The crystallophone is another mallet instrument with flat bars of plate glass.

Conclusion

In this article I have attempted to discuss the science of the glass harp and the armonica and to mention several other glass musical instruments whose acoustical properties have not yet been studied. We invite musicians and instrument designers to bring (or send) interesting new instruments to our laboratory for study.

References

[1] T. D. Rossing, "Acoustics of the glass harmonica," *J. Acoustical Society of America* **95**, 1106-1111 (1994); reprinted in *Glass Music World* 1994.
[2] T. D. Rossing, *Science of Percussion Instruments*, World Scientific, Singapore, 2000.
[3] G. H. Koopmann and A. D. Belegundu, "Tuning a Wine Glass via Material Tailoring—An Application of a Method for Optimal Acoustic Design," *J. Sound and Vibration* **239**, 665-678 (2001).
[4] R. E. Apfel, "Whispering waves in a wineglass," *American J. Physics* **53**, 1070 (1985).
[5] T. D. Rossing, "Wine glasses, bell modes, and Lord Rayleigh," *Physics Teacher* **28**, 582-585 (1990).
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