Laser Phase Synthesis [XXI VII III I]

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1 PROJECT DESCRIPTION

Laser Phase Synthesis [XXI VII III I] is a sound and light performance by audiovisual artist Derek Holzer and electroacoustic composer Luka Aron. It is informed by the historical Audio/Video/Laser system developed by Lowell Cross and Carson Jeffries for use by David Tudor and Experiments in Arts and Technology (E.A.T.) at the 1970 Japan World Exposition in Osaka, Japan [1]] [2]. A more detailed discussion of the historical background of the project can be found in the *Laser Phase Synthesis* paper presented at this conference. Our current project employs digital audio synthesis, modern laser display technology, and a close collaboration between sound and image composition to illustrate the harmonic progression of a musical work.

A laser display functions by deflecting the beam of a laser with a pair of mirrors mounted on galvanometers to create repeating patterns from two input signals, X and Y, at a given frequency in Hz. In our work, these deflection signals are sent from a digital audio interface controlled by the Pure Data application. Composing sounds for the laser display requires careful control of the frequency, amplitude, and phase relationships between two or more channels of audio, since interesting sounds do not always produce interesting laser visuals. Nor are the sounds which produce interesting laser visuals always interesting by themselves. The shapes drawn by a laser display follow the principles of Lissajous figures, where signals with integer harmonic ratios will display a stable figure, as seen in Figure 1. Signals with inharmonic relationships will be unstable and appear as visual noise. Signals approaching a harmonic relationship will appear to rotate in space at a rate equal to that of an acoustic beating frequency (i.e. the absolute difference in Hz between the two). Amplitude modulation of the signals drawing a figure can be used to impress one waveform's shape visually upon another, while changes in their phase relationship produce the illusion of a figure rotating in three dimensional space.

These concerns can add quite an additional burden to the creative process of a musical composer, instrumentalist, or vocalist, particularly if they are not familiar with techniques for creating XY vector graphics. The Laser Phase Synthesis instrument used in our performance simplifies these requirements to the simple harmonic relationship of a monophonic audio channel to the laser's deflection frequency. This direct relationship between sound and image in a single electronic instrument creates a feedback loop in the interaction process, within which sounds are crafted specifically for their visual effect alongside their musical expressiveness.

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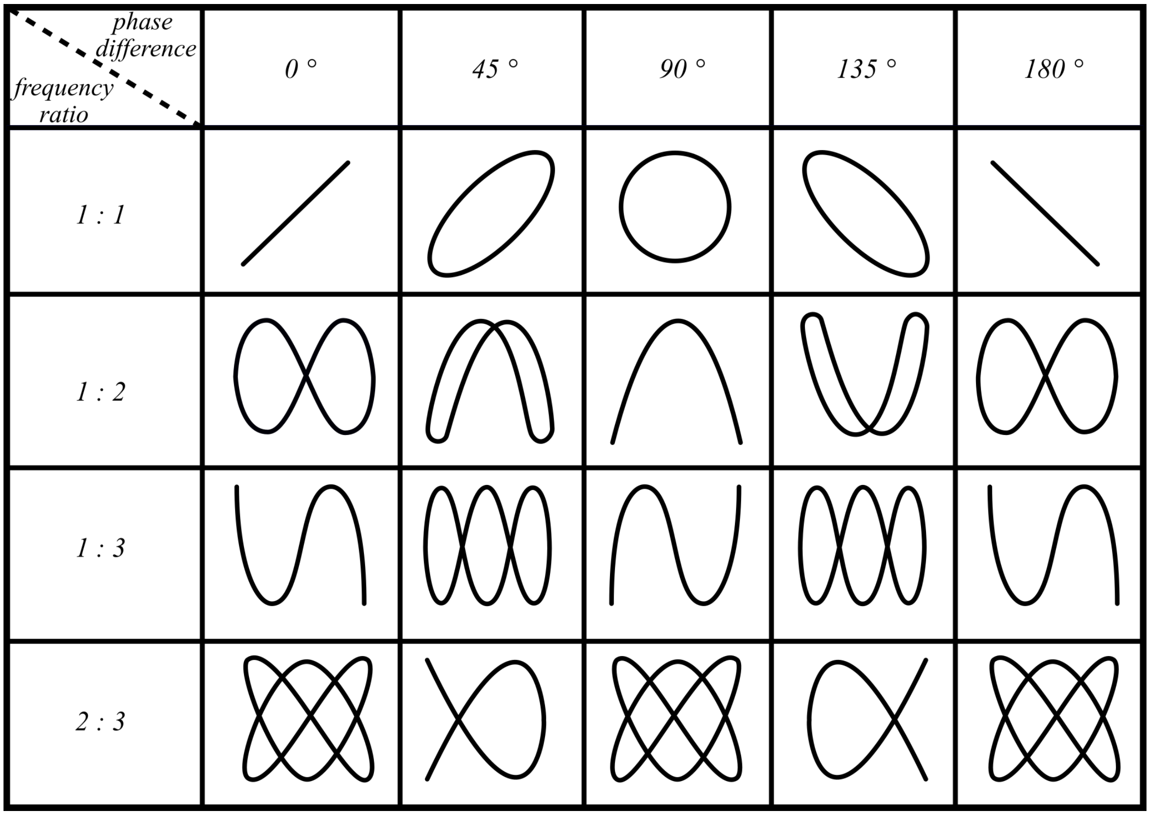

Fig. 1. Harmonic and phase relationships of Lissajous figures.

The Laser Phase Synthesis collection of Pure Data patches uses a single input signal to modulate the amplitude of the two carrier signals comprising the basic shape of the figure. Typically, two sine waves with 90 degree phase difference are employed as the carrier, resulting in a circle whose size is modulated by the waveform of the input signal. Other carrier waveforms can also be used, resulting in different basic shapes which are parabolic or rectilinear in nature. Other parts of the instrument allow for controlled adjustments to size and position of the laser drawing, tilts and rotations in three dimensions, morphing between different shapes, multiplexing a number of simultaneous shapes, and modulations of the laser beam's brightness and color.

One musical tuning system ideally suited to the precise control of harmonic relationships is extended just intonation. This system employs ratios of whole numbers as its pitch material (1/1, 3/2, 5/4, 7/4. . . .) [3]. Just intonation is based on the harmonic series and subharmonic series, where the harmonic series consists of integer multiples of the fundamental frequency (1/1, 2/1, 3/1, 4/1, 5/1. . . .) and the subharmonic series comprises integer submultiples of the fundamental frequency (1/1, 1/2, 1/3, 1/4, 1/5. . . .) By comparing the harmonic and subharmonic ratios, as shown in Figure 2, one can obtain their common partials. Certain combinations of harmonic series will have several partials in common, giving way to the possibility of modulating between them. It is a system derived from the observation of certain auditory and acoustic phenomena, such as difference tones and (non)-beating, as well as the periodicity of composite sound waves.

H A R M O N I C S →

27	1/1						9/5						9/8	
25		1/1					5/3					5/4		
23			1/1											
21				1/1			7/5			7/6	3/2		7/4	
19					1/1									
17						1/1								
15		6/5		10/7			1/1			5/3		3/2	5/4	
13								1/1						
11									1/1					
9	4/3			12/7			6/5			1/1		9/5	3/2	9/8
7				4/3							1/1	7/5	7/6	7/4
5		8/5					4/3				10/7	1/1	5/3	5/4
3	16/9			8/7			8/5			4/3	12/7	6/5	1/1	3/2
1										16/9	8/7	8/5	4/3	1/1
	27	**25**	**23**	**21**	**19**	**17**	**15**	**13**	**11**	**9**	**7**	**5**	**3**	**1**

← *S U B H A R M O N I C S*

Fig. 2. Common partials of the subharmonic-related harmonic series used in *Laser Phase Synthesis [XXI VII III I]*.

In the work *Laser Phase Synthesis [XXI VII III I]*, the fundamental 1/1 frequency was assigned a value of 25 Hz, which matched the initial drawing frequency of the laser forms. The ratios were multiplied by this frequency to derive the exact frequency values of the partials in Hz. Three other subordinate fundamentals, each containing their own subset of unique harmonic partials, were chosen (4/3: 33.333 Hz, 8/7: 28.571 Hz, 32/21: 38.095 Hz). Subsequently, their order was determined by calculating their respective closest relative. An excerpt of the resulting sequence is illustrated in Figure 3.

During the performance of the piece, the drawing frequency of the laser remains matched to the 1/1 fundamental frequency of the partials, even as this fundamental changes through the musical composition. This allows for a wide range of movement, both visually and audibly, while maintaining a close harmonic alignment. The primary timbres used as sonic material for *Laser Phase Synthesis [XXI VII III I]* are sine waves, along with samples of several gongs and

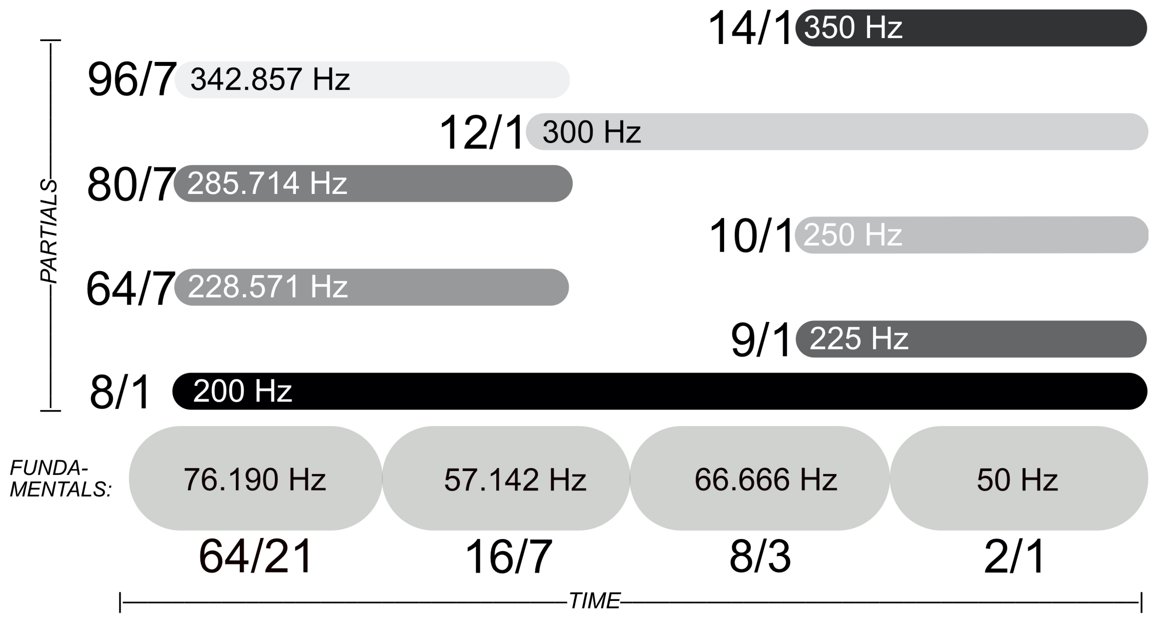

Fig. 3. A timeline of the fundamental and partial frequencies, derived from a laser drawing frequency of 25 Hz, during in the first section of *Laser Phase Synthesis [XXI VII III I]*.

bells. While the sine waves were tuned to precision in the Pure Data environment, they interact with the inharmonic spectra of the percussion instruments, resulting in rich interference patterns apparent in both sound and image.

Beyond the basic amplitude modulation of the Laser Phase Synthesis instrument, using a monophonic mix down of the audio composition as modulator of a circular carrier shape, three dimensional rotations and color modulations of the figure add additional visual complexity. The signals driving the laser are not mixed back into the performance audio. They are only seen in the shape of the laser. Smoke is used to create a volumetric illusion with the laser beam. A selection of some of the resulting patterns can be seen in Figure 4. While a professional laser projector is used in this particular performance, similar results could be realized using more frugal techniques involving old oscilloscopes, hacked CRT monitors, or even mirrors mounted on speaker membranes as described in our full paper for this conference, *Laser Phase Synthesis*.

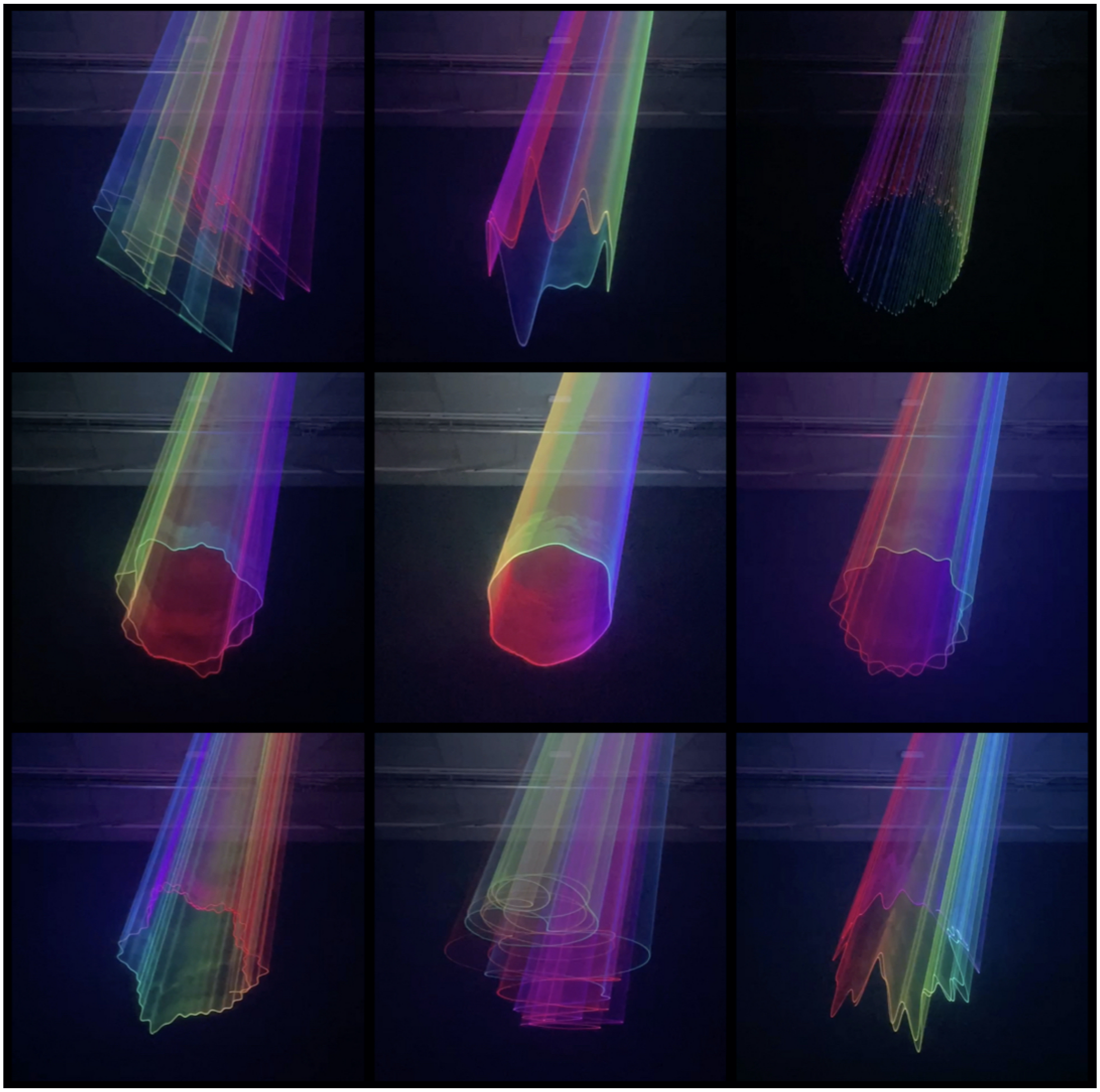

Fig. 4. Audiovisual figures from the November 2022 performance of *Laser Phase Synthesis [XXI VII III I]*.

2 TECHNICAL REQUIREMENTS

2.1 Laser Requirements

- The laser must be securely clamped to a lighting truss or similar, with safety cable in case of clamp failure
- Every part of the laser beam must be minimum 2.5m above any area where the audience is located
- There can be no audience, venue staff, or other performers within the projection area of the laser beam whenever the laser is in use

- There can be no reflective or easily flammable materials anywhere within the laser projection area, and a fire extinguisher should be available
- The venue should designate one safety steward responsible for observing these precautions any time the laser is in use
- The projection surface should be white and untextured
- Please provide one smoke or haze machine of suitable power for the performance space
- No other illumination should be present during the performance

2.2 Sound Requirements

- One 12 channel audio mixer with two aux send/return pairs (e.g. Mackie 1642 or 1202)
- Stereo pair of XLR outputs from mixer
- DI box as required (if mixer outputs are not XLR)

2.3 General Requirements

- One table 100 x 60 cm at 70 cm height
- Table should be placed facing the stage so that performers can see the projection and hear the sound from the PA
- Two chairs)

3 PROGRAM NOTES

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4 MEDIA

The video file submitted with this music program proposal documents a 15 minute performance of *Laser Phase Synthesis [XXI VII III I]* which took place during the DAVAMOT conference at Dalarna Audiovisual Academy in November 2022. Both the visual and sonic components of the performance were based on a pre-programmed sequence of harmonic progressions, however the audiovisual transformations were manipulated in an improvisational manner live by the two performers.

ACKNOWLEDGMENTS

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ETHICAL STANDARDS

The research resulting in this performance has taken place within the context of Derek Holzer's doctoral research at KTH Royal Insititute of Technology in Stockholm, and has been funded by the Swedish Research Council (2019-03694). We declare that there are no conflicts of interest. Any public performance utilizing laser equipment carries the risk of eye damage as a result of accidental exposure to laser radiation. We ensure that every precaution – meeting and exceeding legal requirements – is taken to avoid such accidents on the part of the audience, venue staff, other performers, and ourselves.

REFERENCES

[1] Lowell Cross. 1981. The Audio Control of Laser Displays. *db, The Sound Engineering Magazine* 15, 7 (July 1981), 30, 34, 38–41.

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[3] David B. Doty. 2010. *The just intonation primer : an introduction to the theory and practice of just intonation.* Just Intonation Network, San Francisco, California.