From a Guitar Maker's Notes:

Sebastian Stenzel's „Enhanced Wood"© soundboards

by Sebastian Stenzel

> *"It is not my intention to argue here about the merits or demerits of recent developments in the art of guitar construction, but I would like to add that it is, in my considered opinion, a debatable virtue to search for greater volume of sound at the expense of sound quality."* - Julian Bream, 1987

In 2009 a guitarist came to my workshop to order a double top guitar.
I asked him why he – knowing about my reservations regarding these guitars – came to me with this request. He said he was convinced something good would come out of me addressing this method of construction. I told him that I had given some thought about where my dislike of the sound of double top soundboards stems from, especially since the basic concept of double top construction does make sense. I had analysed what, in my opinion, causes the misperformance of double tops, and I had also come up with a possible solution how to maintain the positive properties of double tops without the negative.
This guitarist, a physicist by profession, could easily follow the explanations of my ideas. The meeting ended with him having commissioned the first Stenzel guitar with an *Enhanced Wood*© soundboard.

This first guitar with *Enhanced Wood* soundboard turned out very well, with exactly the sound properties I had envisioned. I have waited for 10 years before now publishing this invention, because I wanted to be sure that no problems materialized after construction. There were no such problems, and the guitar, as well as the six other *Enhanced Wood* guitars I have built since, keeps getting better and better, just as my traditionally built ones do. I considered applying for a patent, and even had a the necessary patent research done, but then decided to rather make it available to everybody.

Some introductory explanations are necessary, though, to understand the concept of *Enhanced Wood* soundboards:
Double top (also called composite) soundboards are mostly made of two thin layers of wood (in most cases cedar) with a layer of 'Nomex', a honeycomb-structure made from aramid fibres glued in between with either polyurethane or epoxy glue. Some makers also use a solid layer with or without holes, or thin strips of balsa or another light wood[1], instead of Nomex. In all cases, the aim is to increase the so-called tonewood-coefficient

[1] Matthias Damman had been making laminated soundboards with wood strips when Gernod Wagner, another German guitar maker, suggested to use 'Nomex', which at that time was already a household name in lightweight construction.

(sound velocity to mass) or, in plain English, to make a stiffer and lighter soundboard, which – in theory – would boost the efficiency of the soundboard, resulting in a louder guitar.
Such guitars have found approval of quite a number of guitarists for a number of reasons. Beauty of sound is usually not among them. The reasons are:

- the guitar sounds loud (to the player at least, soothing what I once jokingly called the collective inferiority complex of the classical guitar community)
- the guitar plays easier in the right hand (the reason for this is the greater stiffness of the soundboard)
- good balance (often wrongly attributed to the double top construction, in truth rather a result of the successful measures of double top makers against the very bad balance of many earlier double tops).

These reasons combined give many players a sense of security, especially on stage, which is not a small feat in a music scene, where nps (notes per second) and fingerboard acrobatics seem far more important than musicality.

Unfortunately, the greater loudness of double top guitars is only for the player, or someone in close proximity to the instrument, to enjoy. In most cases, such guitars do not sound louder than traditionally built guitars, if you go only a few meters away, and many actually show a very poor balance when heard from a distance and fail to project well even in a small concert hall. Now, think of Julian Bream playing his Hauser guitar[2], not known for great volume, for an audience of 2000 people, and the music carrying to the very last row. How is that possible? It is easy to understand when you consider these three facts:

- the human ear (and brain) is most sensitive to frequencies in the range of 2000 to 4000 Hz (about 20 times as sensitive as, for example, a note with 100 Hz).[3]
- our brain calculates an average loudness for any note. It does not attribute different loudness to the many different partials that make up that note.
- directionality of sound radiation depends on frequency: low frequencies are radiated almost spherically, i.e. in all directions from the source. Higher frequencies are radiated rather focused perpendicular from the emitting surface (i.e. the guitar soundboard). That means, the sound intensity of low frequencies diminishes much faster with distance than that of higher frequencies.

If we looked at a frequency response curve of a traditional guitar like Bream's Hauser, we would see that it shows a high average sound intensity in the range of 2 to 4 kHz with relatively flat, well-dampened resonance peaks, and relatively little energy spent on the three most important resonances: that of the air-volume, the fundamental mode of the soundboard and of the back respectively. A typical double top guitar, by contrast, shows

[2] Bream used quite a number of guitars, among them were six guitars by Hauser I (1928, 1936,1940 (loaned), 1944, 1947, 1950) and one Hauser II, 1957, as well as several guitars from other makers, many modeled after Hauser I guitars. However, it is a 1973 Romanillos guitar he made the greatest number of recordings with. All of these guitars are traditionally built.

[3] For single frequency sinus tones, which do not exist in nature.

typically the highest output in the bass range and very high, narrow pointed resonance peaks, but a rather low average level between these peaks, especially in higher frequencies.
Add this to the facts above, and the explanation is obvious: the sound energy of the double top is emitted mainly in the bass, where the sound intensity diminishes quickly with distance and the sensitivity of hearing is lower anyway. But up close, it sounds loud, because the brain is averaging the loudness of all partials. The traditional guitar, on the other hand, does not sound very loud to the player, simply because it is not, but carries wonderfully, because of high output in the frequency range where our hearing is most sensitive, and the total sound intensity diminishes less with distance.[4]

This is, so far, my generalized analysis of what is, in my opinion, the main problem with double tops: they are too stiff to allow higher modes with a sufficient amplitude, i.e. modes radiating well in the range of 2000 to 4000 Hz. They usually have a high output in the bass range, but only a rather poor and very unbalanced output in higher frequencies.

But there is more to it:
As I see it, the guitar (the following holds true for any instrument) has developed in a long evolution involving highly interdependent factors, namely the material and its properties, the characteristic sound and physical laws. Over centuries, these three factors have converged to an equilibrium that essentially defines the instrument. Nothing in the (technical-) design is accidental. Not the shape, not the materials chosen, not the dimensions of shape and material.
Unarguably, the most important element of the guitar is its soundboard. It is made of coniferous wood. One of the most salient properties of coniferous wood is its pronounced anisotropy. Anisotropy implies actually a number of properties, but not to make it too complicated here, it means that certain properties of the wood depend on direction: mainly stiffness and sound velocity change with respect to the angle of the wood fibre, with the extreme cases being parallel to the fibre and perpendicular to the fibre. A double top has practically lost this anisotropy completely, or at least it is dramatically reduced. But this doubtlessly significant physical property of the soundboard has always been a factor in the evolution of the guitar and to take this factor out means destroying the equilibrium we call 'guitar'. To expect the outcome to be equal to the result of centuries of evolution is, in my opinion, daring at least.[5]

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4 As long as you are within a certain angle near the perpendicular of the soundboard. In a guitar concert, it is better to sit in the last row in the middle than in the first row at the side.

5 Some might argue that any cross bar also does away with anisotropy, but this is not true. Unless you plaster the soundboard with cross bars, its sound velocities and hence its shapes of modes does reflect the anistropy of the soundboard itself.
Another objection could be that it is the soundboard as a whole which matters, not single properties. This is, in my opinion, only partially correct. And even though we can make pretty good models of guitar sound with the infinite-element-method and coupled mass-spring-models, or analyse the sound with modal analysis, what is really going on in detail is not fully understood and the question what makes a master guitar in physical terms is still elusive.

The fact that many double top makers try to give back some anisotropy to their double top soundboard[6], seems to me to prove that this point is more than just moot traditionalism.

Having understood the problem, I could easily see several alternative ways of raising the tonewood-coefficient, which would not compromise the wood's anisotropy. I went with my most promising idea, and the first reason I called it *Enhanced Wood*, is that the anisotropy is not only preserved, but even enhanced. This idea is incredibly simple and follows a very old principle every child understands when it folds its first paper plane: a fold adds stiffness to the paper. With an accordion fold, a rather stable plate can be made similar to a corrugated steel roof. Two more layers of paper and you have corrugated cardboard, which we all handle almost daily. My idea was to apply this principle to the soundboard by giving it an inner corrugated glue joint, which I can make even stronger by embedding carbon fibre fleece in it. The result is a sound board, with similar overall stiffness to a traditional one, but a higher ratio of stiffness along the fibre to stiffness across the fibre. This allows the soundboard to be made thinner and simultaneously increases its stiffness in the direction where it is most needed, thus allowing more vibration of the soundboard especially in higher frequencies.
The player experiences this as an enhanced dynamic range and enhanced malleability of the sound, which are the second and third reason for its name.

Please do not get me wrong: I am not claiming this to be a better soundboard than a traditional one. But it may be an alternative to double top/composite soundboards. I also do not want to withhold that it shares one drawback with them: in case of damage, repair can be critical, and if severe enough, the soundboard might need to be replaced completely. For a player seeking a maximum of musical expression, however, it might be an interesting alternative indeed.

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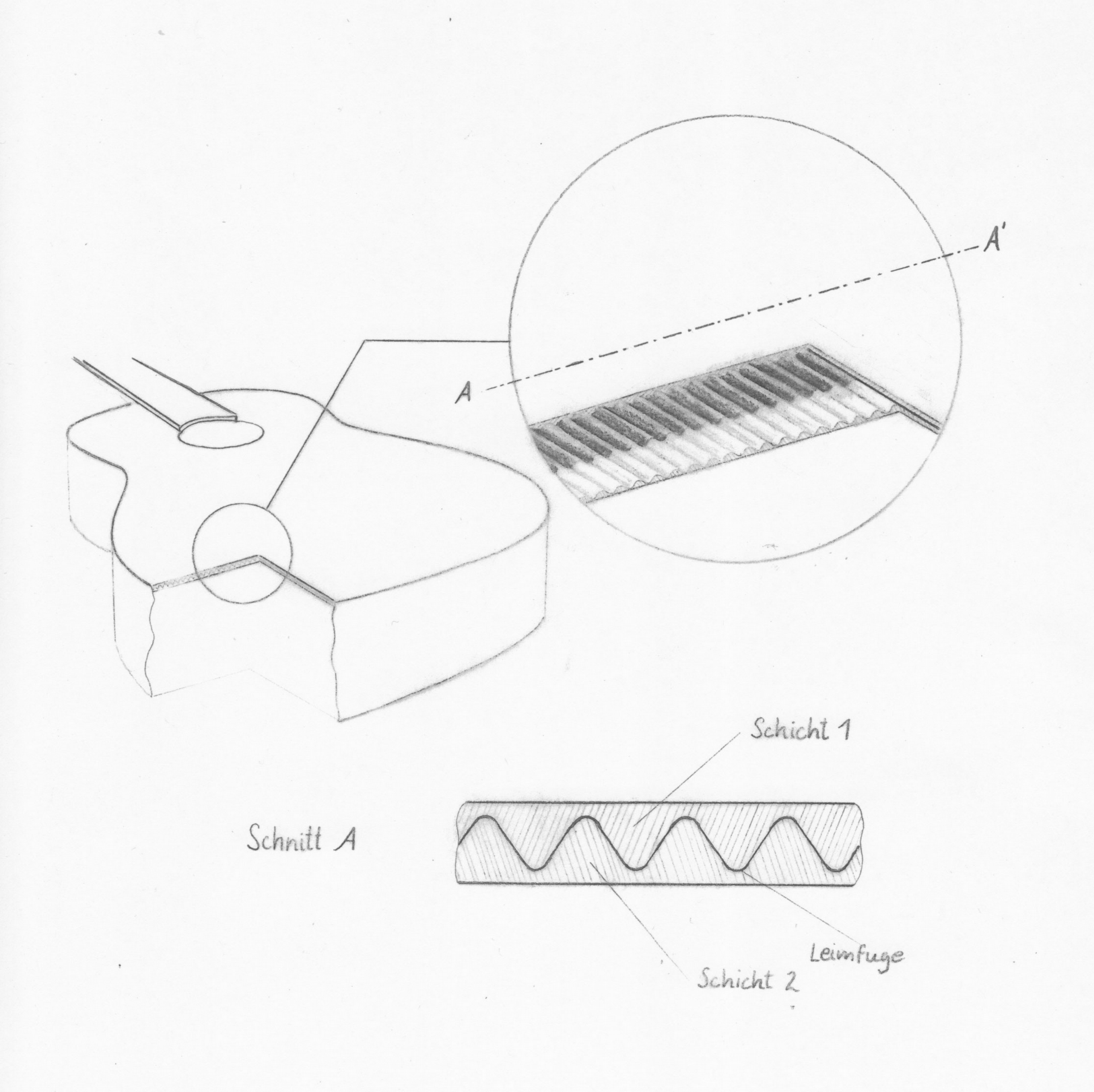
[6] The most common example for this is arranging the balsa strips in a fish bone pattern. It hepls a bit, but the result is nowhere near the natural anisotropy.



A drawing from the patent application I never filed. Any instrument maker who wants to make *Enhanced Wood* soundboards has my permission to do so on the condition of stating the origin of the idea.