MEMORY-TECH

Ultimate High-Quality CD "UHQCD" developed by Memory-Tech

Burrow into the Mystery of UHQCD sound quality

Ultimate HQ HiQualityCD

AEx オーディオ銘機賞 Audio Excellence Award 2016
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An article published in Audio Accessory

Phile web AV/オーディオ/ガジェット ファイルウェブ PHILEWEB

A visit to Memory-Tech's Tsukuba Plant, where the UHQCD was developed

Text:Masanori Hayashi *Photos:Mikihiko Kobayashi(Saikousha)*

After 30 years since the birth of the CD, Memory-Tech Corp. has developed the Ultimate High Quality CD (UHQCD). This is truly the ultimate audio media, featuring technology Memory-Tech has cultivated, such as the Crystal Disc, to satisfy even the most demanding audiophiles, like those who would like to listen to audio on a super high-quality CD format. To learn some of the secrets of this unique technology, Masanori Hayashi paid a visit to Memory-Tech's Tsukuba Plant, where the new CD—already adopted by numerous record labels—is in production.

■What is UHQCD?

Streamlined productionfrom mastering to packaging

A new era in disc media is ready for us to explore. It's called Ultimate High Quality CD, or UHQCD, developed by Memory-Tech Corp. in Japan, as the ultimate evolution of HQCD. How is it different to the conventional Audio CD? I visited Memory-Tech's Tsukuba Plant to find out.

Memory-Tech is Japan's one of the largest CD manufacturers. At its extensive plant, a streamlined production process is underway, covering everything from disc mastering and replication, to printing and packaging. The impression is of a highly automated, state-of-the-art production facility. (The company also has a plant at Gotemba, formerly belonging to Toshiba EMI.) I am greeted by a group of staff, including Production Manager Shigenori Ishii, Technology Manager Ryoji Higashi and Takashi Numano.

Some background knowledge: Whereas conventional CDs are made of polycarbonate, UHQCD uses photopolymer, a light-activated resin that offers excellent pit transcribability. As with Blu-ray, a blue laser is used for cutting master discs (as opposed to a red laser for CDs). Additionaly, since cutting is performed at a constant speed with minute precision, the interaction of light and media enables a huge leap in audio

quality. I had done the homework to understand this much, but I was amazed to learn just how much deep research and ingenuity went into developing the UHQCD.

Using photopolymer to improve transcribability

You might already know something about the CD manufacturing process. A stamper that has been encoded with pits representing the audio source is used to press polycarbonate melted at 300-350C in an injection molding process, to reproduce the pits. "Since polycarbonate resin is highly viscous, however, the stamper pits cannot be made very deep with this technique, so some imperfections in the transfer are unavoidable."

With HQCD, a format developed six years ago, a less viscous polycarbonate material was used, but limitations remained. Now, with UHQCD, a totally new process has been adopted. "We used a photopolymer that remains high fluidity at room temperature. We pour this on a rotating base, causing the material to spread evenly by means of centrifugal force. By pressing the material with a stamper to sandwich it and then irradiating it with UV light, the liquid photopolymer solidifies instantly." The theory is that the force of the stamper causes the resin to penetrate every nook and cranny, resulting in excellent transcribability; in practice, this requires a detailed process of setup and tuning.

This method of using a photopolymer was established as a technology for Crystal Disc. UHQCD differs in that polycarbonate is used as the substrate instead of glass. A newly manufactured production line also enables UHQCDs to be created just as fast as conventional CDs—just 5 to 6s per disc. "So, mass production of UHQCD is not a problem at all."

Creating reflective layer of different thicknesses, test-listening

I asked to see some of the company's precious data, such as real measurements of transcribability. Comparing reproducibility at the internal, middle, and external regions of a disc, relative to the stamper, which serves as the master, the reproducibilities of a conventional CD in the tangential direction are 85%, just under 80%, and 78%, respectively, at the three points. Thus, the reproducibility deteriorates with distance from the disc center. (See graph below.) This is reportedly because the flow of resin during the injection molding process deteriorates towards the outside of the disc.

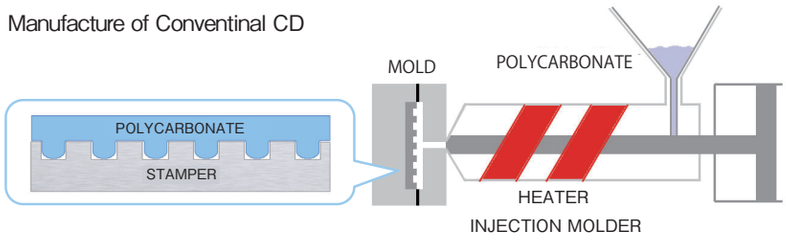
In contrast, UHQCD has little variation in transcription, with an average of 90% reproducibility. I understood just how much better the reproduction fidelity of UHQCD is than that of CD, both in the radial and tangential directions. "At the external region, you can see an improvement of more than 10% in reproducibility."

What about the eye pattern we see when comparing output HF signals? The difference compared with CDs is obvious: HQCD is far superior. This seems to be related to differences in the reflective layer. CDs use aluminum, while UHQCD uses a silver alloy, like HQCD. The more highly reflective layer provides UHQCD greater amplitude width. This is also a

Japanese audio critic Masanori Hayashi learned about UHQCD technology from the Memory-Tech Development Team

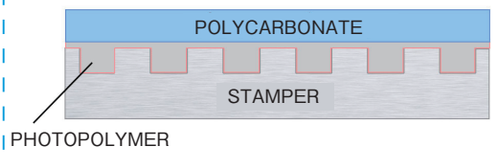
Technological Point of UHQCD

Manufacture of Conventinal CD



Melted raw material (polycarbonate) is poured into a metal mold (stamper) to create a form. However, since polycarbonate is highly viscous, the polycarbonate does not reach deeply into the pits (grooves) of the stamper, so the transcription tends to lack precision.

Manufacture of UHQCD



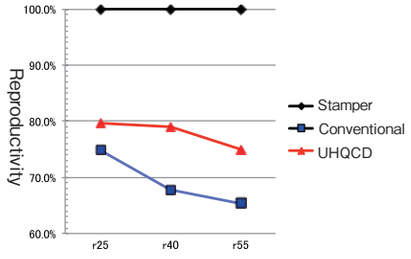
A low-viscosity photopolymer is injected between the stamper and the pre-made substrates. Since the photopolymer reaches the depth of the pits, the transcription performance is vastly improved.

Features of UHQCD

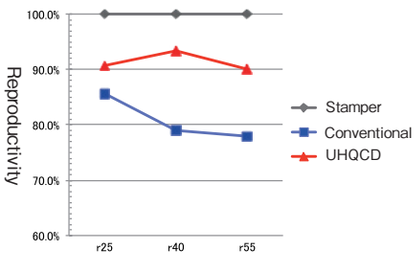
●Conforms to the conventional Red Book Audio CD standard, so it can be played on any CD player.
●A revised transcription method enables improved reproducibility of masters.
●Reduced manufacturing costs enables discs to be priced similarly to conventional Audio CDs.

Transcribability

Radial transcribability measurements



Tangential transcribability measurements



contributing factor to the improved audio quality.
In the case of UHQCD, five types of reflective layer of different thicknesses were evaluated. The final selection was made based on various experiments. A very analog way of tuning!

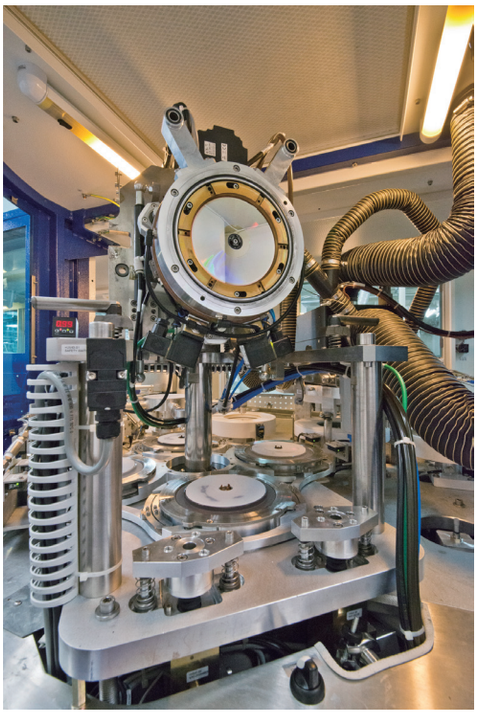
■UHQCD production line

A dedicated power supply to ensure stamper audio quality

So, how are UHQCDs actually manufactured? The order of my tour of the plant was not always in the same order as the manufacturing process, but I was guided through the most important processes of the production.
All the work is performed inside a clean room. Firstly, this is the stamper recording room(❶), also known as the cutting room, where visual inspections are performed to check for warping of the stamper and perforations in the perfect circles. "Radiating a special light makes it easy to see any scratches."
Along with the audio quality of the casting, the quality of the stamper is also very important. Thus, the disc signal recording equipment and other machines are provided with separate power supplies, which are each directly connected from a cubicle. Masters for CD, DVD, BD, and even next-generation UHD Blu-ray are all manufactured in this room.
Next door is an inspection room of the disc manufacturing process(❷). This room has three pieces of inspection equipment costing almost twenty million dollars each, which evaluate electrical characteristics. "When we press the first disc, we come here to evaluate it. Without checking the first sample disc, we never proceed to mass production."
The injection molding machine is huge(❸). In the photo you can see the injection tube, which is the heart of the machine. Pellets are fed in from above, and the melted polycarbonate is injected by a stamper. Transparent polycarbonate substrates are produced one after another.

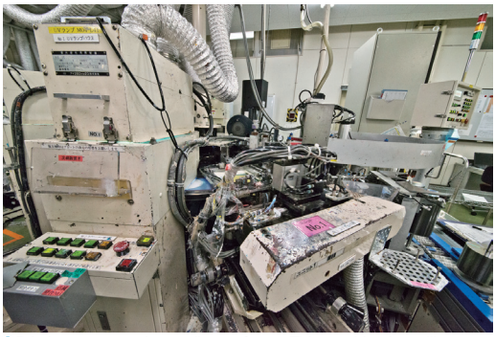
❶The stamper recording room, used to create the masters for mass duplication of CDs. Stampers for conventional audio CDs, Blu-ray discs, etc. are created using high-precision data control

❷Disc inspection room. Only after passing the severe testing, the first CD goes to mass production



❹This is where the most important section in UHQCD manufacturing, the stamper, is attached.Except for a few days at New Year and midsummer, production continues 24/7

❸Electric injection molder in the disc production room



❺Printing room to print on disc surfaces. This machine is a silkscreen printer

Machine structure with fantastic precision

We come to the UHQCD production line. A transparent polycarbonate substrate can be seen on the table. Liquid photopolymer is dripped over the substrate, and the arm moves to under the stamper. With a rumble, the stamper presses down on the substrate, with a machine-gun-like sound, and a UV flash lamp flashes from below. In an instant, the photopolymer become hardened, and the pits are transcribed. It sure is fast.

Next time, they open the cover of the machine(❹). Usually, it is opened when replacing stampers. This is the secret of UHQCD production. We are amazed by the sophoisticated structure of the stamper.

Finally, we are guided into the printing room. I observed silkscreen printing(❺) and then offset printing. I carefully observed the printing work on Blu-ray discs, such as movies and animations. In the case of offset, a white base was printed by silkscreen then four-color(CMYK) was printed by offset. Both processes were very fast.

■Checking the audio quality of UHQCD

Comparing UHQCD, DDP Master, and conventional CD

I had an opportunity to listen to UHQCDs and compare three audio media: a DDP master, a UHQCD, and a conventional CD. The point of test-listening is to assess how closely the quality of the master audio source is reproduced. I tried listening to and comparing three audio media played on the special player (DDP-100) that Memory-Tech developed for DDP masters.

It was clear that the UHQCD was closer in quality to the DDP master. It seemed far superior to the conventional CD in all aspects. It had a greater frequency range and sense of spaciousness, more finely detailed information and more realistic tonal colors.

The difference was most easily discernible with vocals. On the CD, Chiharu Matsuyama's(❻) voice seemed restricted and tight. There should have been refreshing high tones, like those heard in the DDP version, but he sounded muddy and lacking in sharpness.

On the UHQCD, the sound is much fresher. The sound was disentangled and good from every standpoint; it was dynamic and clear, as if liberated. The lower tones were also rich, enabling an expressive and rich performance; there was power in the sound.

The nuances of Emi Fujita's(❼) voice were more detailed than on the conventinal CD. I felt her voice transparent, with a distinct clarity and sharpness. Her voice sounded similar on the DDP master, and the quieter voicings on the UHQCD were particularly good. Her soft expressions and breathing sounded amazingly fresh and gentle, and the sound field of the strings extended effortlessly outward from deep inside the speakers.

Moved by the beautiful and resonant vividness

I compared the UHQCD and DDP Master of Kanae Izutsu (❽), and UHQCD seemed to lack nothing of the DDP master. They are almost the same. With its fresh, detailed sound, and vividness, it is comparable to a Crystal Disc.

How about some classical and jazz? Aki Takahashi's "Satie" is an excellent recording that captures the rich hall tones of a church. With its vivid presence and the famous Fazioli depth and beautiful resonance of the lower tone, we should listen to it on UHQCD. Listening to Coltrane's hot, erupting performances feels like being at one of his live gigs in the 1960s.

Is all this due to differences in pit transcription performance and reflectivity? Even compared to HQCD, which made use of improved materials, the audio quality of UHQCD is on another level entirely—"ultimate" you could say—so I am convinced that CDs still have a future. With this quality, UHQCD has a huge potential. There is no doubt that it can satisfy the ears and hearts of audiophiles.

Hayashi compared the audio quality of a DDP master, a UHQCD, and a conventional CD in the listening room. The test speakers were B&W 802 Diamond

Reference Discs

❻
Chiharu Matsuyama
PLATINUM BEST
PONYCANON
PCCA.50198

❼
Le Couple&
Emi Fujita
~The greatest gift~
PONYCANON
PCCA.03141

❽
Kanae Izutsu
TOKI NO MANIMANI 5
diskunion
ULB-32

Using a DDP-100 player developed by Memory-Tech to play both DDP masters and CDs, I listened to different media under the same conditions.

UHQCD was far superior to the conventional CD, with greater frequency range and sense of spaciousness, more finely detailed information and more realistic tonal colors.

Experimental evidence of UHQCD audio quality, using wavelet analysis

Text:Masanori Hayashi *Photos:Norio Tashiro*

"Same digital data, but why we hear the different sound?" The motivation of Memory-Tech to develop the UHQCD is such a simple question. In order to solve this mystery, Memory-Tech has started a new research project with Hiroshima City University, which is "to investigate the difference of the sound humans really hear". They employ the wavelet analysis to challenge this great mystery.

Mission: reproducing master quality sound

Memory-Tech Corp. has strived meticulously to achieve high-quality audio reproduction. The Ultimate High-Quality CD (UHQCD) is an ultimate audio quality new madium that Memory-Tech released in 2016. Their motivation for developing the UHQCD came from the question: "Why does the audio quality of CDs differ, despite being a digital medium?" To find an answer to this question, Memory-Tech has conducted various experiments and verifications over the years.

It is known from experience that sound quality varies if the model of the laser beam recorder(LBR) used to cut the stamper is changed, or even when the disc pressing line or pressing conditions are changed. It is a fact that by severely listening, CDs created from the same master can sound different. Believing that it is valid to "without prejudice, trust the phenomenon" Memory-Tech's mission is finding ways to faithfully re-create the sound of the masters provided by record labels. Achieving audio reproduction that is as close as possible to the master source. In pursuit of this ideal, Memory-Tech has focused on the "transcribability" of the pits in discs.

In 2008, Memory-Tech released the HQCD disc, which employed a new (highly transparent) polycarbonate. In 2016, after extensively revising its manufacturing methods, focusing on the fluidity of the material, it released a new disc media format, UHQCD, employing a photopolymer, which is light-activated resin material. This technology came from Crystal Disc, the highest quality audio media on the market.

Crystal Disc employs an expensive glass substrate. This product reproduces quality of masters more closely than any other type of CD. "Is there any way to mass-produce discs of this quality at a low cost?" This question drove the company to take up the challenge to develop UHQCD.

A research meeting was held at the Memory-Tech head office

To review, the difference between the conventional Audio CD and Crystal Disc or UHQCD lies in the molding process. The conventional Audio CD employs "conventional injection molding" and the other "wet embossing molding" methods.

Discs have pits (sound grooves) cut in spirals from the inner to the outer region. With injection molding, polycarbonate (high viscosity) melted at high temperature is poured in from the center and for this reason, the closer it gets to the outer region, the cooler the material becomes, causing a progressive loss of pit transcribability.

In fact, they developed one hypothesis: in the case of a conventional CD, is there not a substantial difference in sound quality between the inner and outer regions of the disc? To test the difference in sound quality between inner and outer regions, they created one CD with the same track, a few minutes long, repeated over and over. The evaluation is that, the closer you go to the outer region, the greater the gap in sound quality compared to the master.

What about wet embossing molding? I visited Memory-Tech's Tsukuba Plant to inspect their state-of-the-art production lines. Photopolymer is a smooth, highly fluid material. To make a UHQCD disc, photopolymer is applied evenly to the substrate and then a stamper is pressed over the photopolymer from above. The photopolymer is then irradiated with a flash of UV light, and is instantly polymerized. Compared to conventional injection molding, this method results in high pit transcribability, and less difference between the inner and outer regions. This leads to the hypothesis that improving pit transcribability makes it possible to reproduce audio that is closer to the master in quality.

Starting research with Hiroshima City University

Although transcribability can be quantified, it is extremely difficult to quantitatively evaluate differences in audio quality. Memory-Tech commissioned an analysis by Prof. Shunsuke Ishimitsu of the Sound Design Lab of the Hiroshima City University Graduate School of Information Sciences. This project is a joint research with Kenta Ueyama, a graduate student of the lab.

Selecting a music source suitable for discerning differences in audio quality, a master CD was created with the same music

source repeated on all tracks from the inner to outer region. From the same stamper, a conventional CD and UHQCD were made. Then, they detect slight differences in electronic signals from a CD player among the three types of discs: the conventional CD, UHQCD, and master CD.

Differences in materials result in different audio impressions. This is a truth that many audiophiles feel strongly. To objectively evaluate such subtle differences, a method called wavelet analysis was used in this study.

Wavelet analysis is considered more accurate than Fourier analysis in modeling our sense of hearing—it is the analysis method that most closely resembles human audio processing.

A characteristic of wavelet analysis is that in low-frequency bands, time resolution is poor but frequency resolution is good, while conversely, in high-frequency bands, time resolution is good but frequency resolution is poor. This is very similar to the resolution characteristics of the basement membrane of our sense of hearing. The basement membrane responds to high frequencies at the entrance of the cochlea, so time resolution is good. However, low frequencies are handled deep inside the cochlea, so time resolution is poor. These features fit well with wavelet multi-resolution analysis.

After a blind sound quality listening test, wavelet analysis was conducted on the same discs.

"Golden ears" detect significant differences in listening tests

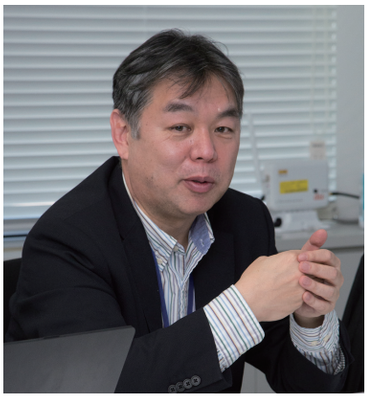
Firstly, blind listening tests were performed. A total of 22 test subjects participated: 10 university students and 12 Memory-Tech employees(MTe). The latter included four Memory-Tech sound quality evaluators, known as "GEs" (golden ears).

The subjects listened to the same music source played on CD and UHQCD and were asked to judge which sounded better. Those who chose UHQCD answered correctly (2-point discrimination test). The results are shown in Fig. A. In test 1, a total of 11 of the 22 answered correctly. Six out of the 12 MTe and five out of the 10 university students were correct. All four GEs were correct.

The subjects said: "the CD sounded flat and lackluster." "The low tone was weak and muffled." On the other hand, "UHQCD sound was spacious with punchy drum sounds." "The high-pitched sounds of cymbals were clear and there was reverberation in the tom-tom drums."

Note that in the table, detection was at a "significant difference" of 0.05. "Significant difference" is a statistical term that indicates the level of certainty that a result is not just accidental or due to errors. A value of 0.05 indicates a high level of confidence and the lower the value, the more significant the result.

This table shows that the ratio of selecting UHQCD was 50% for MTe and 47.5% for the students. This does not show a significant difference. The success rate of GEs (professional sound quality evaluators), was 75%. These results demonstrate that students and other ordinary people cannot distinguish the two media easily, but that trained people can. The level of "significant difference" for the GEs was 0.038, which is considerably lower than 0.05.



Kenta Ueyama

Prof. Shunsuke Ishimitsu
Sound Design Lab
Hiroshima City University

Blind test results

TEST	No. of correct answers			
	Total	MTe	Students	GE
1	11	6	5	4
2	13	6	7	2
3	9	5	4	3
4	10	7	3	3
No. of questions	22	12	19	4

Fig.A Results of the blind listening test

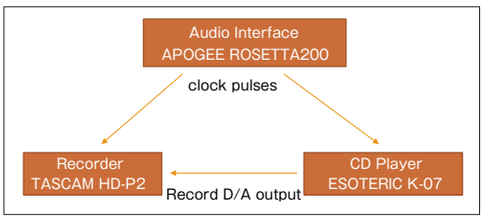


Fig.B Audio device used for the analysis

Displaying sound pressure differences on a graph

Next, Prof.Ishimitsu and Mr.Ueyama conducted a wavelet analysis. The level of correlation is calculated by multiplying (inner product) each stereo L/R music signal by its wavelet. From this analysis, discontinuities and frequency components can be extracted at different points in the music.

In this study, to eliminate the influence of electrical noise, a moving average from 20 music sources was calculated. Then, the differences between the L and R channel signals (representing different sounds) were calculated to conduct the wavelength analysis. This was done in order to make the differences clearer. If differences can be detected, differences in the sense of spaciousness can also be verified with data.

The audio device used for testing with sound pressure differences is shown in Fig.B. The master CD, conventional CD, and UHQCD were played back on the same CD player. A rubidium clock was used to synchronize the clocks of the playback system and recording system at 44.1 kHz, and recording was performed from the player's DA output (analog output) to a recorder.

So, what did the analysis results show? I will explain how to read the results figure. Take a look at Fig. C. This figure shows the sound pressure level difference between the master CD and conventional CD against frequency (Hz) on the vertical axis and time (s) on the horizontal axis. The color indicates the sound pressure level of the right gradations. For example, the circled area means that at time 250 μs, the sound pressure difference (logarithmic scale) at 2 kHz is approximately −70 dB.

Fig. D shows a graph of the sound pressure difference at the outer region of the CD and the UHQCD. The pressure difference relative to the master CD was −100 to −110 dB for the UHQCD and −80 to −85 dB for CD. This result shows that the UHQCD was able to more closely reproduce the sound from the master CD, compared to the CD.

Ideally, the master CD should have no variation between the inner and outer regions, but since the audio source is recorded onto physical media, some variation is inevitable. Looking at the pressure difference between the inner and outer regions, which is typically substantial, the difference for UHQCD is −95 dB in the 1–10 kHz band and −105 dB at the next lowest band. These are negligible differences. (See Fig. E). From the perspective of the dynamic range of a conventional CD, these differences are akin to looking out to sea from land. They are at the level of insignificant errors.

The pressure difference between the inner and outer regions with conventional CDs is typically high, around −75 dB. This can be seen in the transcribability graph too, with a more dramatic gap at the inside and a mild gap at the outside of the disc, which correlates well with wavelet analysis.

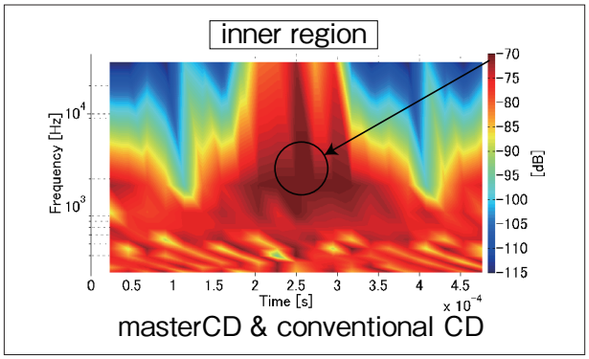


Fig.C Interpreting wavelet analysis results

The UHQCD certainly has some slight variation across the disc surface compared to the master CD, but in this respect, it is closer to the master CD than a conventional CD.

As shown above, wavelet analysis makes it possible to express a slight difference in human sound perception as a difference playback signal.

There needs to be further experimentation and analysis, but it is groundbreaking that pit transcribability contributes to the fidelity of reproduction of a master audio source. The results suggest that the UHQCD developed by Memory-Tech is capable of reproducing sound that is very close to the quality of the audio master provided by record labels.

My own impressions of test listening at the Tsukuba Plant is that UHQCD is far superior to the conventional CD in terms of frequency range, spaciousness, detail, precision, and dynamic expression. UHQCD is clearly closer in character to the master. UHQCD has great potential for Hi-Fi sound and it can certainly satisfy the ears and hearts of demanding music fans.

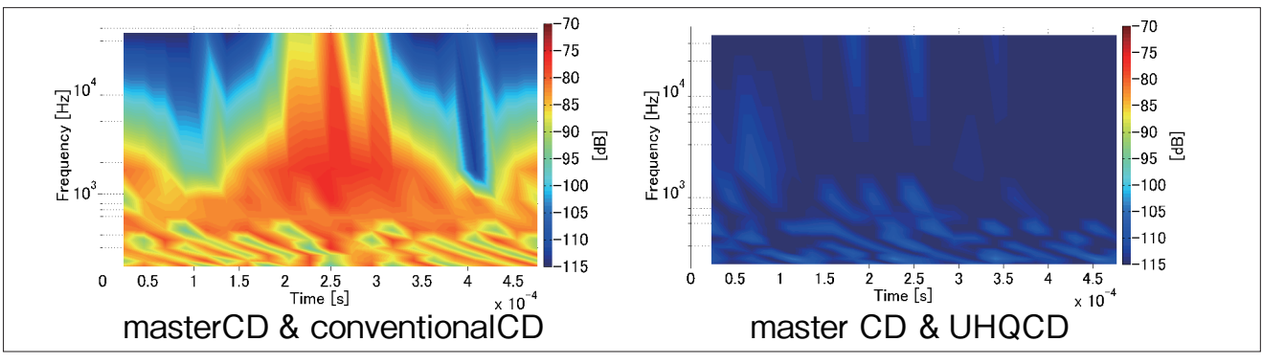


Fig.D Sound pressure difference at outer region

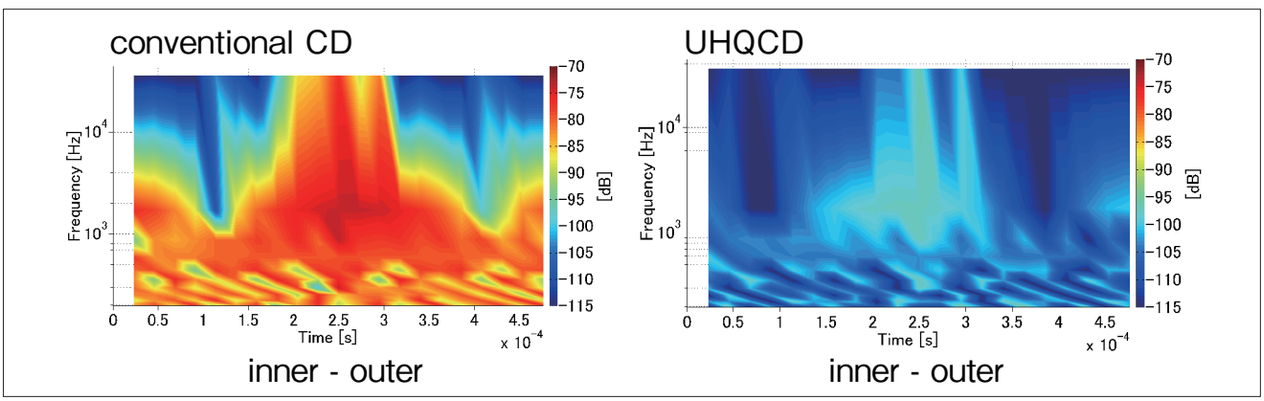


Fig.E Sound pressure difference on surface

We would like to thank Editage (www.editage.jp) for English language editing.